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THE NIAGARA POWER PLANT OF THE ELECTRICAL DEVELOPMENT CO., OF ONTARIO.*

II.

METHODS OF CONSTRUCTION.

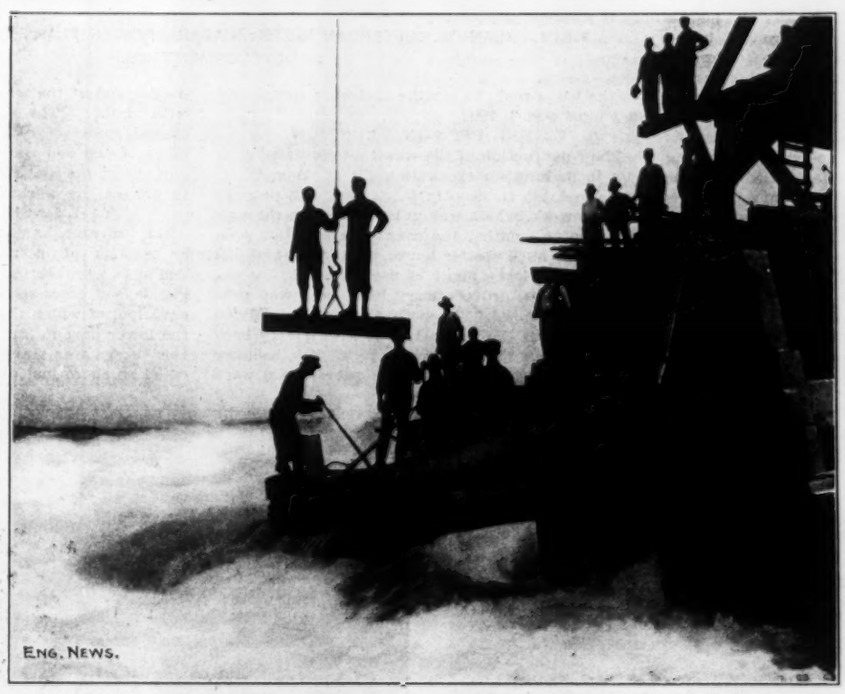
Interesting as is the design of the latest great power plant at Niagara Falls, as described in our issue of Nov. 9, it is probable that its chief interest to many will be the difficulties surrounding the construction work and the methods by which they were overcome. The design as worked out called for two bold propositions in the line of construction work. The first was to build a cofferdam in the very midst of the rapids above the Canadian Falls, and the second was to drive a tunnel under these same rapids to an outlet behind the cataract. It is to these two features of the work that we shall devote the most space. It should be noted first, however, that Mr. M. L. Peppard has been Superintendent of Construction for the Electrical Development Co. since the beginning of work.

COFFERDAM CONSTRUCTION.

The location of the head works and power house outside the shore line necessitated unwatering about 11.5 acres of the river bed by cofferdams, to permit of their construction. The location of these cofferdams is shown by Fig. 1; there were two built, one inclosing the entire works and the other inclosing the wheel pit excavation alone. The purpose of the smaller dam was to enable work on the wheel pit before the large area inclosed by the main dam had been completely unwatered.

GOVERNING CONDITIONS.—In order to appreciate the task before the engineers in constructing the cofferdams, the conditions of current, depth of water and nature of river bottom require explanation. No soundings had ever been made to determine the depth of water over the area to be laid dry. The fierce rapids emphasized by cascades had made such investigations practically impossible. It was assumed by the engineers that the depth of water was about 8 ft., but this estimate proved far short of the actual depth which in places was 26 ft. The current undisturbed by structures was 17 ft. per second. The bottom was a boulder strewn ledge itself irregular in surface. The views of Fig. 2 show the character of the bottom clearly, and some of the other views, particularly those of Figs. 6 and the front page picture, show the character of the currents. It is safe to say that no other cofferdam work has ever been conducted under such difficult conditions.

COFFERDAM STRUCTURES.—The design of cofferdam determined upon was a crib structure of timber; more accurately described the structure consists of two parallel timber cribs with a space between filled with puddle. The drawing, Fig. 1, shows the structure in diagram plan and Figs. 3 and 4 show sections at the various points marked on the plan. The features to be noted in these drawings are the variations in width to meet the variations in depth and the fitting of the bottoms of the cribs to the irregularities of the river bottom. No attempt was made to anchor the cribs to the bottom otherwise than by the weight of the filling and the natural anchorage furnished by the roughness of the boulder covered ledge. Altogether the cofferdam structure, per se, was a simple one; the complication came with its construction under the conditions described.



COFFERDAM CONSTRUCTION IN THE RAPIDS OF THE NIAGARA RIVER.

METHOD OF CONSTRUCTION.—The general method of constructing the main cofferdam was to build it out crib after crib from the shore connection at the upstream end. The contract for the work was awarded to Barry & McMordie, of Niagara Falls, Ont., on March 14, 1903, and active work was begun on April 2, following. The crib work was started from the original shore line 415 ft. above the upper end of the wheel pit. For the first 416 ft. the construction was comparatively simple the cribs being built in place. The flow, it should be said, had been largely diverted from this portion of the river bed by the cofferdam of the Ontario Power Co. located just above and completed in December, 1902. The small amount of water here intercepted by the new dam was allowed to flow through culverts left in the crib work near the shore end.

Between the second and third angles of the cofferdam (Fig. 1) a heavy flow was intercepted, the water becoming deeper and the current more rapid. A change in the method of construction was necessitated; the cribs could no longer be built in place. They were built in the river upstream from the cofferdam and by means of cables from the shore were floated into place with the current. After the work had proceeded in this way a short distance beyond the second angle, it was found that the water was being backed up behind the dam and threatened to flood a portion of the forebay unwatered by the Ontario Power Co. To prevent this occurring a spur dam (Fig. 1) was constructed upstream along the edge of the heavy flow; this spur dam was extended as occasion demanded and ultimately reached an intersection with the cofferdam of the Ontario Power Co. It was built by the contractors for the main dam.

At a point 576 ft. from the shore measured along the dam a decided fall in the elevation of the river bed was encountered; the water increased in depth from 17 ft. to 24 ft. in a distance of 48 ft. This deep channel continued for about 50 ft. and then gradually shoaled to a depth of 19 ft., which depth was generally maintained until the cascades were reached. Because of the great depth of the water the width of the cofferdam was increased and a new method of placing the cribs was made necessary. The enlargement of the dam structure is clearly shown in Figs. 1, 3 and 4. The new method of crib construction is explained by the sketch Fig. 5. In order to break the force of the current where the water rounded the end of the crib a fender, was constructed of heavy timber. This fender rested for about two-thirds of its length against the upstream face of the completed dam and the other third of the length projected beyond the end of the finished dam. It was held in place by the pressure of the water and by three cables reaching from its shore end to winches set on the spur dam. The cribs were framed in the slack water

*Part I. describing the general design of the plant and its structures was published in our issue of Nov. 9.

below the cofferdam and brought into position in the lee of the fender by means of stout tackle operated from a traveling derrick at the end of the dam. By paying out the cables and by aid of the derrick the fender was "hitched" along to a new position as fast as the cribs were completed.

The whole work of moving the fender and framing and placing the cribs was arduous and full of difficulties. As the dam progressed the water was raised behind it to an elevation about 7 ft. higher than normal level; this caused, as may readily be seen, a very swift current around the dam end. The pressure on the end of the fender was enormous and at a distance of 690 ft. from the shore along the dam, it was so great that the cross-braces to which the cables were attached parted and the fender was carried away. A new fender of stronger and heavier design was constructed; this fender served its purpose until the cascade was reached, but in trying to pass this obstruction it was broken up and carried away. By this time, however, the dam was running so nearly parallel with the current that it was possible thenceforth to place the cribs without a fender.

Following the completion of the cribwork came the task of making the dam water tight. For this result dependence had been placed upon the sheeting and puddle fill; the task was to get the sheeting and puddle into the crevices and hollows so as to close the water way. This proved a task of the greatest difficulty and was finally abandoned by the contractor and assumed by the engineering force employing day labor. The process was simply to drive the sheeting as tight to the bottom as possible, and then to close the holes and crevices by patches placed by divers or by any other convenient means. Finally the puddle space was filled, the clay being brought in by railway cars on a switch track on the cribwork.

The total length of the main cofferdam along its center line is 2,137 ft., and the average progress of construction was 150 ft. per month. While the work was a task of considerable hazard only one man lost his life; a workman missed his footing and fell into the river and was carried over the falls. The point at which this accident occurred is shown by the front page view, which was taken at the cascades and shows the launching of a crib in the swift current. A more general view of the cofferdam is shown by Fig. 6, which gives a very striking idea of the amount of leakage before the work had been rendered tight.

SMALL COFFERDAM.—The small cofferdam was essentially a part of the wheel pit work; it was built solely that work might be started on the ber bracing was used to hold the sheeting for the dry space. This sheeting consisted of a double thickness of 1-in. boards, the boards breaking joints and being scribed to fit the bottom. While the dam was completed on Nov. 7, it was not possible, owing to the rough bottom and to seams sketch Fig. 7. The total amount of this s about 6 ins.; its cause is a matter of spe and its consequences have been serious vious works and not without importance present construction. In Fig. 8, which is of the wheel pit excavation, it will be noti

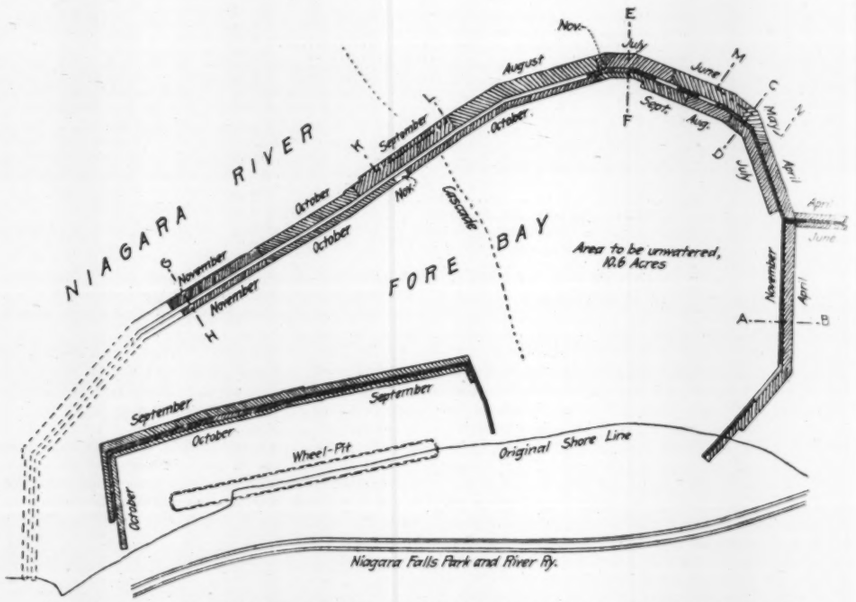


FIG. 1. PLAN OF COFFERDAM WORK: NIAGARA POWER PLANT OF THE ELECTRICAL DEVELOPMENT CO.

in the ledge rock, to lay the enclosure completely dry until Dec. 1, 1903.

WHEEL PIT CONSTRUCTION.

The construction of the wheel pit consisted simply in making an excavation 421 ft. long, 27 ft. wide and 135 ft. deep in ledge rock. To prepare for the work, which was to be carried on through the winter months, the area of excavation was housed in by a shelter house 48 ft. wide and 425 ft. long. A large plant of derricks, hoisting engines, pumps, drills, quarry bars, etc., was provided and housed. The method of excavation was simply to cut the vertical sides with quarry bars and blast out the intervening rock. The hoisting was all done by derricks. The quarry bars were the far end of the wheel pit has been mattressed with timber. The squeezing of the side walls caused spalls of rock to be detached from the faces of the end walls with almost the force of gun shots; the mattressing of the walls was done to protect the workmen from these flying chips.

TAIL RACE CONSTRUCTION.

The tail race, as described in our issue of Nov 9, consists of a main tunnel 1,935 ft. long and of two branch tunnels each about 500 ft. long. Fig. 9 is a cross-section of the main tunnel excavation, of which the upper part is in shale and the lower part in limestone. The construction of this tunnel was started by means of a shaft, located on shore just above the falls, from which a

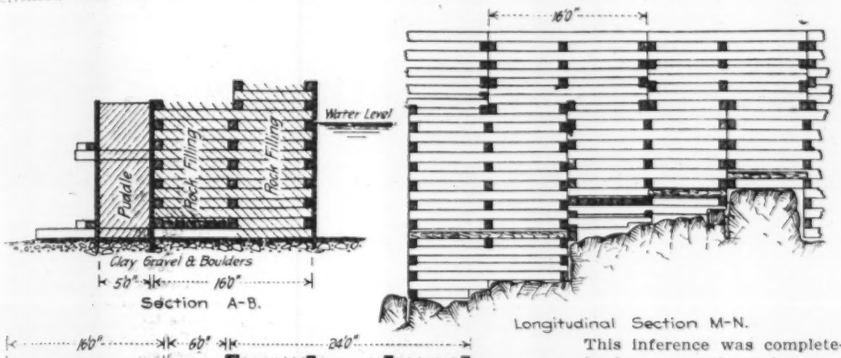
FIG. 2. VIEWS OF COFFERDAM ENCLOSURE UNWATERED SHOWING CHARACTER OF BOTTOM ON WHICH CRIBWORK WAS BUILT.

excavation of the wheel pit without waiting for the completion of the main dam. Work was begun on the dam on Sept. 2, and it was completed on Nov. 7, 1903. It consisted, like the main dam, of a double line of cribwork with a dry space between. The outer crib varied from 7 to 12 ft. in width, depending on the depth of water which was 15 ft. at the deepest point; the inner crib was uniformly 7 ft. wide and was carried up to the water level, above this point stout timadopted as being more economical than channeling machines, and also because they gave a rough surface with which the brick lining could be bonded more closely.

In constructing the wheel pit a curious phenomenon was noted; exactly the same phenomena appeared in the wheel pit work of the American and Canadian plants of the Niagara Power Co. This phenomenon was the closing together of the sides of the wheel pit, as indicated (exaggerated) by the lateral drift was extended to the tunnel proper. This general arrangement is shown clearly by the plan, Fig. 10. The contractor was Anthony C. Douglass, of Niagara Falls, N. Y.

SHAFT CONSTRUCTION.—The first work was the shaft construction. Work was begun May 1903. For a depth of 16 ft. the shaft penetrated loose material which admitted water from the river very freely. A pit approximately 46 × 39 ft. was excavated in this loose material and carried

to a depth of 2 ft. below the level of the water in the river; in this excavation a cofferdam was constructed surrounding the mouth of the shaft. Because of the very open nature of the fill on which the cofferdam rested, considerable trouble was experienced with the inflow of water, and it was found that the water rose in the shaft to a height of 16 ft. above the grade of the drift before finding its level, thus indicating that the water came from the heavy spray under the falls striking the cliff and finding its way through fissures whose openings were approximately at this elevation.



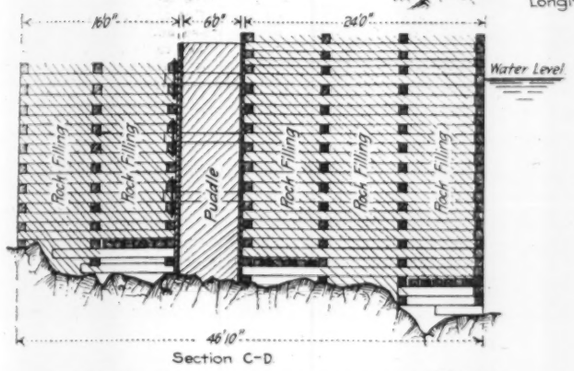


FIG. 3. TYPICAL SECTIONS OF CRIB COFFERDAM.

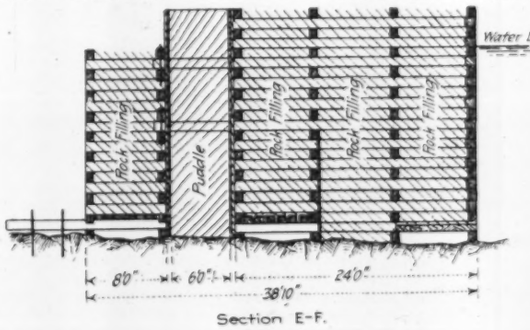
This inference was completely borne out by subsequent events.

A heavier pumping plant was installed and on Oct. 28 the water was lowered and construction again begun. It was determined to find out just how thick the barrier of rock was between the working face and the face of the cliff. Holes were drilled in the working face varying in length from 18 to 22 ft., indicating a barrier of solid rock about 12 ft. thick, and beyond this a softer rock somewhat disintegrated but of unknown thickness, none of the holes penetrating to the face of the cliff. In all 18 holes were drilled, and as the flow into the drift was increasing in volume and gaining on the pumps, it was decided to load the holes and blast away the barrier. In addition to the dynamite used in the holes, ten cases of 60% dynamite were placed against the face and the drift was allowed to flood before firing. The conditions at this moment are shown by Fig. 12.

not until June 25 that the excavation reached the original rock surface. The seamy surface rock was removed for a depth of 4 ft. to an impervious rock stratum and the final shaft timbering placed and surrounded by a wall of concrete which effectually cut off water entering the shaft. The construction, as outlined, is indicated by Fig. 11. Once the solid rock was reached, the progress of sinking the shaft was rapid. The dimensions of the shaft were 15 × 7 ft. in clear of all timbering, and it was completed to subgrade, a depth of 150.2 ft. on Aug. 28. During August the shaft was sunk through a depth of 101.5 ft. and in addition 15 ft. of the drift, 14 × 7 ft., were driven from the bottom.

DRIFT CONSTRUCTION.—The drift from the bottom of the shaft to the tunnel was designed for construction purposes only. It left the shaft at elevation 366, and, with a slight fall in grade, intersected the tail race at about springing line or 23 ft. above the normal high water in the gorge. It was given a section of 7 × 14 ft. The construction was through shale rock and gave little trouble until at a distance of 385 ft. from the shaft a branch drift reaching to the face of the cliff behind the falls was undertaken. The purpose in constructing this branch drift was twofold; first it was planned to get an opening through which spoil would be disposed without hoisting it up the shaft, and, second, it was planned as a sort of exploration gallery to determine the distance of the cliff from the workings and the conditions which existed behind the falls where the main tail race was planned to discharge. These good intentions of the engineers resulted chiefly in troubles.

Up to the time that the branch drift was begun the work had been very dry, a No. 5 Cameron pump working at intervals was sufficient to remove the water. These favorable conditions continued until the branch drift had approached to within about 14 ft. (estimated) of the cliff. Then, on Oct. 9, a blast developed a seam in the roof and a rush of water flooded the workings. Pumps were installed and the water removed sufficiently to permit resumption of work. Preparations were being made to begin drilling when a fall of rock from the roof gave entrance to increased volumes of water which again flooded the drift. It was



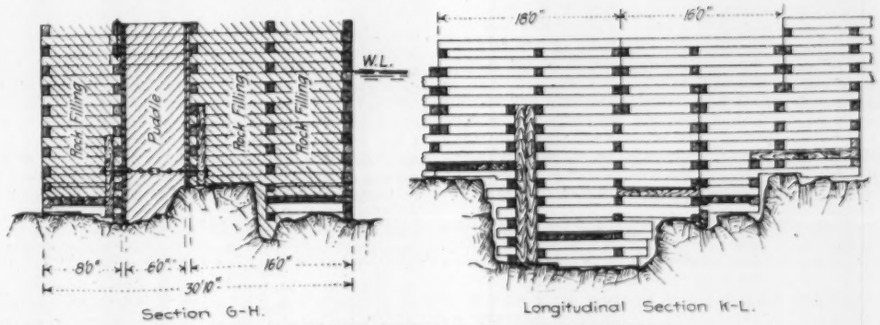


FIG. 4. TYPICAL SECTIONS OF CRIB COFFERDAM.

which shows the solid rock barrier a, b, c, d and the talus beyond. The blast broke down the solid rock barrier and opened a through cut through the talus out to the sheet of water and down to an elevation about 12 ins. below the drift roof. In Fig. 13 d, e, shows the bottom of the cut; as will be seen, the remaining talus formed a dam which backed up the water in the drift to the level of about a foot below the roof.

There now followed some anxious moments. According to popular belief it was an impossible task to get behind the falling sheet of water forming the Canadian Falls. To get at the opening from the shaft meant a journey through some 400 ft. of tunnel filled with water to within 12 ins. of its roof. Yet the opening had to be reached or the work abandoned. The choice of two evils finally settled on the journey through the tunnel. Volunteers were called for and the three foremen of miners, John Davis, Michael Abbott and "Shorty" Minor, responded. A flat-bottomed boat was procured from the Maid of the Mist Steamboat Co. and taken down the shaft to the entrance to the flooded drift.

The boat rode too high to pass under the roof; it was then loaded with three boxes of dynamite, coils of wire, tools and ballast until it did clear the opening. Finally the men got in and the journey was begun. Lying on their backs the men propelled the boat by pushing with their hands against the roof a few inches above. The only light was that from the miners' torches. In this manner the voyagers finally arrived at the hole through the cliff and stood, the first human beings, behind the Canadian Falls of Niagara. The dynamite was unloaded and attached to the rocky dam as well as could be, then the boat voyage back to the shaft begun, the men uncoiling the firing wires as they proceeded. On the return of the boat the blast was fired, but with no appreciable effect on the water level in the drift. A second boat voyage to the cliff was begun, but after proceeding a short distance the boat swamped and sank and the men were compelled to swim for their lives to the shaft. A raft was then built and tried but it was a failure and a second voyage through the drift was abandoned.

The only resort left was to get at the obstruction by creeping behind the falls, and this was finally decided on. The engineer, Mr. Beverly R. Value, M. Am. Soc. C. E., the contractor, Mr. Anthony Douglass, and two foremen undertook the task. Starting from the Scenic tunnel these men roped together worked their way along the top of the talus until, 450 ft. from the Canadian side of the falls, they reached the opening from the drift. This first journey was made to demonstrate the feasibility of the trip; succeeding journeys were made by men with dynamite until by open blasts the rocky barrier was broken down and the cut through the talus deepened to grade. Through this trench the water in the drift was readily drained away. As soon as this was done, the trench was widened and a timber shield constructed out from the opening to within about 12 ft. of the curtain of water to protect the men from the heavy spray. The construction of this shield, which was built of 12 × 12-in. yellow pine timbers, was a most difficult and trying operation. The men working under the heavy fall of spray, which came in gusts of such fierceness and strength as to sweep them frequently from their feet, were roped to the heavy timbers, and this

alone in several instances saved them from being swept under the falls.

From the end of the shield a chute was constructed for the disposal of the excavated rock. Work was then resumed on the drift toward the tunnel on Nov. 20. By Dec. 31, 1903, the drift

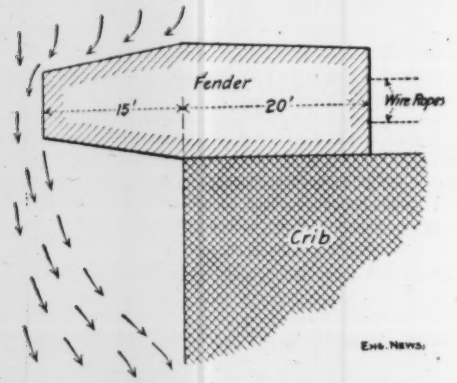


Fig. 5. Sketch Showing Fender for Constructing Cribwork.

excavation was completed, a total excavated length of 741.4 ft., and work had been begun on the main tunnel.

TAILRACE CONSTRUCTION.—The construction of the tailrace tunnel proper was a straightforward task of rock tunnel work. The dimensions of the excavated section are shown by Fig. 9. The material penetrated was shale and limestone, the shale occupying the roof portion, and neither rock carried any water. The shale made it necessary to timber the roof; the view, Fig. 13, shows this timbering at the point where the main tunnel branches to straddle the wheel pit.

The mode of excavation was to drive two top side drifts about 8 × 10 ft. in section, keeping them about 40 ft. ahead of the following excavation. This consisted of the crown cut and the core between the drifts as shown in Fig. 9. The core was blasted first and then the crown section, using 60% dynamite. The remaining bench was taken out in one operation. For that portion of the main tunnel between the drift and the portal the spoil was removed through the drift and discharged under the falls. After the main tunnel portal had been opened, however, the spoil was discharged there. It may be noted here, moreover, that luck favored the engineers, since by some freak of the waters the talus had not formed at the point where the portal pierced the cliff. It is also curious to note that of all the vast amount of spoil from the tunnel discharged at this one point, not a vestige has ever appeared to sight after being grasped by the falling waters, nor has there been external evidence of any sort that anything unusual had occurred to change conditions in the river bottom below the falls.

THE ERECTION OF RAILWAY BRIDGES.*

By Lee Jutton.

It has become the practice of many large railway systems to erect their bridges by a gang of men directly employed by them, rather than by contract work. They have found that the saving in the cost by this method is sometimes as high as 50% and very rarely less than 20%. A great deal depends on the foreman who is in direct charge of the men. If he is careful about the men he hires and is conscientious about his work, as well as being a competent man, there is no doubt but that the work will be done cheaper and the result will be more satisfactory than if done by contract work. Although the foreman reports to the division engineer on whose division he is working, the work of erection is generally under the direct supervision of the bridge engineer of the system.

In this work the question arises whether to use union or non-union labor, and most of the roads have decided in favor of union labor. The men that do this work belong to the Structural Iron Workers' Union and to get into this organization it is necessary for a man to go before an examining board, composed of men who are supposed to thoroughly understand the trade. And I think it is true that most of these examining boards give rigid examinations, as is shown by the fact that quite often men are rejected.

Bridge erection is very dangerous work. The accident insurance companies require a higher rate from a bridgeman than from any other kind of a mechanic. This fact is enough to require that none but experienced men should work in the gang, because should one man be injured or killed by ignorance or inability of another man in the gang, the railway is responsible. Accidents also reflect on the ability of the foreman, because he should anticipate which way a piece of iron is going to swing when hoisted, how much of a load should be put on a rope or cable, how many erection bolts are necessary to hold a member in position before it is riveted, and a great many such things which are constantly arising. The union creates a feeling of fellowship among the men, and for this reason they take more pride and interest in their work. It is true that if union men are employed higher wages must be paid, but this is offset somewhat in the following way: On the roads that employ non-union men the wood work as well as the iron work is all done by one gang, but where the other system is used the carpenter work is done by another gang. On each division of the railway is one or perhaps two carpenter gangs. This gang prepares the falsework and gets everything ready for the iron gang. Then when the iron crew has come and the iron is all in place and finished the carpenter gang returns, removes the falsework and puts on the new deck. The painters follow the carpenters, and thus the bridge is completed. It does not require the skill or experience to be a bridge carpenter that it does to be an iron worker, consequently the wages of a carpenter are lower, and all the work done by the carpenter gang means less work for the iron gang and therefore a lower cost for the job. Quite often an iron worker's first experience as a bridgeman is in a carpenter gang.

For all spans of 150 ft. or less, it is much more economical to use a derrick operated on the railway track for erecting, than it is to use a traveler. The cost of additional falsework for and the erection of a traveler will more than make up for any advantage the traveler might have over the derrick for assembling the different members of the bridge. A derrick built either of steel or wood is well adapted for bridge erection. Most of these derricks are built on ordinary flat cars reinforced for the purpose, but a specially designed steel car is better, and it is quite necessary to have the car made so that it can be readily blocked and anchored for lifting heavy loads. The hoisting engine is placed over one truck and the mast of the derrick over the other. This mast should be about 20 ft. high above the top of the car and consist of three columns, two at the sides and one in the center, made so as to revolve and carry the boom. The mast should be pin-connected at the bottom, so that it can be lowered towards the rear of the car for shipment. The boom should not be less than 40 ft. long. This length is required to put the top chord on a bridge the depth of which is 30 ft. It would also require a 40-ft. boom to set a 70-ft. girder. The boom should be connected with the mast in such a way that it can readily be detached and loaded back on the derrick car when the derrick is to be shipped. Besides the main hoist the derrick should be fitted with two auxiliary hoists on each side at the end of the boom, consisting of 1½-in. rope lines and operated on the spools on one side of the hoisting engine. The spools on the other side of the engine should be used to swing the boom by means of 1¼-in. lines. The derrick for general work should have a safe capacity of not less than 20 tons.

There are two general methods of erecting girder bridges. They may be assembled in their permanent position or they may be assembled directly at the side of their true position and then when they are riveted together they are moved to their true position. The former method is practicable only for through girders where the old bridge is a pile trestle. The girders are lowered to their position on the abutments, then the old bridge is torn out, the new floor system installed and bolted. Then the track is replaced on the new beams and stringers. Unless the trains are unusually numerous the track can be changed in this manner without delaying traffic. After the bridge has all been assembled and the trains can pass over slowly the riveting can be done by shifting the ties when necessary at the different points.

In all bridge work, when the new floor system is put in, the old ties are put on temporarily until the bridge is completely riveted, then the new ties are put on. If the old bridge is a pony truss or some such structure, the position of the truss makes it impossible to set the girders in their permanent position. Of course it would be possible to remove the old bridge and carry the traffic on falsework while the girders were being set, but the better plan is to assemble the new bridge at one side and rivet it together. Then when everything is ready the old bridge is torn out and the new one is moved into position. To do this, all the falsework that is needed is two frame bents, one at the end of each abutment, and the cap of the bent flush with the top of the abutment. An old rail is placed on the top of the bent, then the girder bridge is completely assembled and riveted with the girders resting on the rail. When the old bridge is all torn out another piece of rail is placed on the top of the abutment so as to make a continuous track for the new bridge to be moved into its position on the abutments. A good coat of grease or heavy oil should be put on the rails to facilitate the movement of the girder. The bridge can be moved to position by triple blocks attached to each end. Ten men on each set of blocks are sufficient to pull in a 60-ft. through girder, but a better way if hand power is to be used, is to attach the lines to hand crabs, which are fastened to the girder. If convenient a derrick or a locomotive can be used for power. Another way to move the bridge is to set powerful jacks against the outside girder at an angle of about 45°. The method of assembling at one side and sliding in is almost always used for deck girder bridges.

It is becoming more and more the practice to make all railway truss bridges as long as 150 ft., riveted trusses rather than pin-connected. Large factors in designing railway bridges are impact and traction forces. The heavy locomotives that are used now tend to rack a bridge to pieces and unless a bridge is very rigidly built it will be necessary to redrive quite a number of loose rivets every year, and this adds greatly to the cost of maintenance. The riveted truss is much more rigid than the pin-connected truss and hence it is used wherever possible.

Under ordinary conditions the falsework for a through truss bridge consists of simple pile bents with 8 × 16-in.

FIG. 6. VIEW OF COFFERDAM, SHOWING LEAKAGE BEFORE PLACING PUDDLE FILLING.

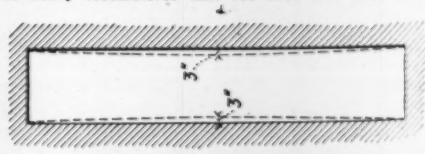


Fig. 7. Sketch Showing "Squeezing" of Wheel Pit Walls.

*Abstract of a paper in the "Technograph" (University of Illinois), 1904-1905.

timbers resting on the caps. The top of these timbers should be 8 or 10 ins. lower than the bottom flange of the new floor beams. The bents should be driven as closely as possible to the old floor beams. If there is no old bridge to be taken down the pile bents should be driven directly under where the new floor beams will come. In tearing out the old bridge, if the stringers are of wood and rest on the floor beams, the first thing to be done is to shift the stringers until their ends rest, not on the old floor beams, but on the falsework. This

Fig. 8. View Inside Wheel Pit Excavation.

having been done the traffic is carried entirely on the falsework and the old bridge can be completely torn away. If the old floor system is composed of steel beams framing into each other, then this old floor system will be blocked up on the falsework so that the old trusses can be taken down. In assembling the new bridge the first thing naturally is to set the bases on the abutments. Then the lower chord is put in its proper position and is supported at the splices by blocking, resting on the falsework. As mentioned before the work of assembling is generally done by a car derrick attached to a locomotive.

A word might also be said here about erection bolts. If the holes in the steel are 15-16-in. diameter, ¾-in. bolts are used in erection. These bolts are from 2½ to 5 ins. long. To adapt them to any grip required they have a long thread and are supplied with washers of varying thicknesses. Thus it is possible for a workman to bolt any two pieces together firmly and quickly.

After the lower chord has been set, the next thing to be done is to assemble the floor system. The work must be done between the time of trains and can be done by parts or all at once and as the number of trains will permit. The old track is torn out and the new floor beams and stringers are assembled. As fast as possible the track is relaid on the new stringers so that the derrick may move ahead to continue the work. By means of blocks and wedges the floor beams are supported on the falsework. The stringers are securely bolted to the floor beams and it is in this manner that the traffic is carried until the bridge is completed and the falsework is removed.

When the lower chord and floor system is installed, riveting can commence and continue while the remainder of the bridge is being assembled. The next thing is to assemble the web members. Beginning at one end, the plumb posts are first erected, then the end posts, and then the other members. Both trusses are assembled as the derrick advances. Next comes the top chord. Generally one section of top chord includes three panel points and quite often it is a difficult matter to erect a section of chord because it must fit the web members at these three points simultaneously. If the lower chord has blocked a little too high or too low at any place, it will cause difficulty when the top chord is put on. After the top chord, all that is left are the portals and top laterals. First the portal at one end is erected, then the top laterals and finally the other portal is erected. Almost always portals can be riveted together on the ground, leaving only the connection to the end posts to be riveted after erection and it is well to design a portal so that this can be done.

Riveting a bridge together in the field plays quite an important part in erection. On a big piece of work, one man has charge of the riveting. Riveting is commenced as soon as the work of erection will permit. If it is a one-span girder bridge, the assembling is completed before the riveting is commenced, but if it is a through truss, the riveting follows the erection of the end truss, that is after the floor system is assembled and the erection of the trusses has begun. It has been found to be quite necessary to inspect all field rivets, whether it be on contract work or day work. On contract work it is readily seen that the foreman will hurry the men in order to reduce the cost, and the result is poorly driven rivets unless they are carefully inspected. In day work, where there is no undue haste, there is the same tendency on the part of the workmen to drive poor rivets. They dislike to go back and redrive rivets, and quite often a rivalry springs up about the number of rivets driven in a day, and this is another cause of hurriedly and poorly driven rivets. Therefore, in order to get good field rivets every one should be carefully inspected and the poor ones should be redriven.

There are two methods of driving rivets; by hand, and by compressed air. Naturally, the first question is the comparative cost, and at first thought it seems as if the air-driving would be more rapid and therefore cost less. But the average cost of air-driven rivets is about the same as that of hand-driven rivets. It is possible to drive more rivets by air than by hand, but this advantage is offset by the cost of operating the air compressor, which requires the constant attention of one man and is a constant expense for supplies and renewals. Air-driven rivets are better than hand-driven rivets. The rapid stroke of the pneumatic hammer will upset the rivet in the hole much better than the slow, heavy blows of the maul. The place where air driving is advantageous, is on high truss work, where the structural details are such as not to allow easy hand driving. Here the pneumatic hammer is used to a great advantage for two reasons: first, because the rivets can be driven quicker and better than by hand; second, because less scaffolding is required than if the maul was used. Naturally the use of the pneumatic hammer is in favor with the workmen because the work is not as hard. Therefore it is advisable to use hand driving on short girder spans and air driving on truss spans.

It is quite important in driving rivets that the excess of stock for the head should be just enough and not too little or too much. If there is not enough excess to form a head, then the rivet can not take its required amount of strain, and if there is too much stock the rivet head can not be driven down tightly against the plate. The length of a rivet for forming a head depends on two things: the size of the head as made by the tool used, and the amount that the rivet upsets in the hole while being driven. The second condition is variable, because some rivets are heated hotter than others and the hot ones will upset more than the others while being driven. The length for forming a head for ⅞ and ⅞-in. rivets is, generally speaking, as follows: For short grips up to 1⅛ ins., where the rivet can not upset in the hole, 1¼-in. is all that is required to form a head, but as the length of the grip increases so that the rivet has room to upset in the hole, then ⅛-in. should be added to the

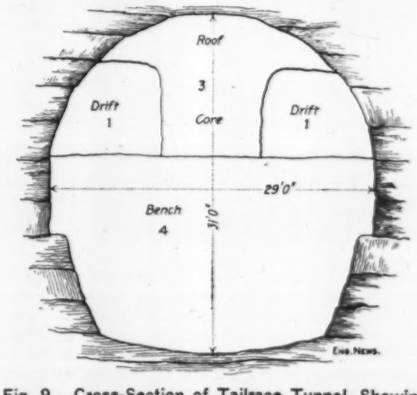


Fig. 9. Cross-Section of Tailrace Tunnel, Showing Sequence of Excavation.

1¼-in. stock for every ⅝-in. increase in length, above 1⅛ ins. For example, a rivet having a 1⅛-in. grip would be 2⅝ ins. long, one having a 1¾-in. grip would be 3⅛ ins. long, one having a 2⅜-in. grip would be 3⅞ ins. long. If this rule is followed it is necessary that the long ones be heated for their full length and not merely on the point as is sometimes done.

In order to get good rivets it is also necessary to have the pieces to be riveted well bolted together before the riveting commences. The holes should be made to match perfectly and the different parts should fit tightly against each other. If this is done the rivets are sure to be snug and tight. The quality of the material used in making the rivets should be closely watched, for a very poor quality of steel is often made up into field rivets. The result is that the rivets will often crack and break while being driven.

It is necessary to have a blacksmith with a bridge crew, because the tools are constantly in need of repair,

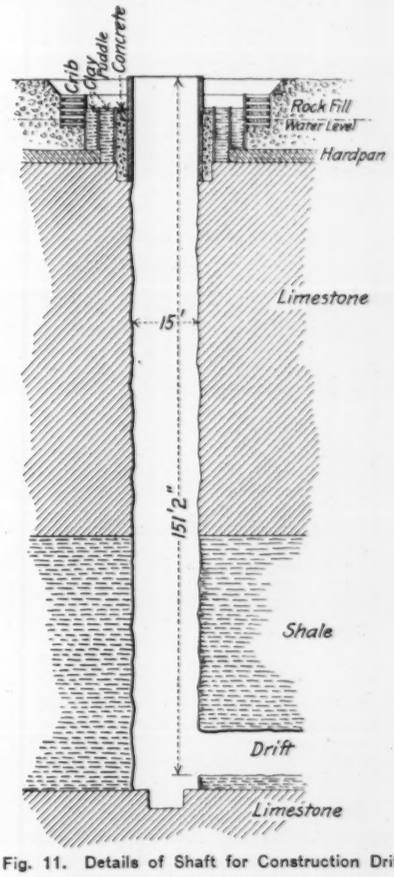


Fig. 11. Details of Shaft for Construction Drift.

and other things arise that need the work of a blacksmith.

In bridge erection, as in all other well conducted affairs, the organization of the crew must be perfect. If there are 20 or more men in the gang the foreman should have an assistant. This is necessary because the gang is often divided in doing different parts of the work. Each man should become accustomed to having a certain part of the work to do. Some men prefer to drive rivets, while others prefer to raise and assemble the bridge, so when once the crew is organized the men should be kept at the work they prefer as much as possible. Four men compose a riveting gang, and the riveting gangs should never be broken into if it can be helped. Always keep the same four men together and each man doing his own special work.

A BROADER FIELD FOR THE STEAM TURBINE.

By "K. H. S."

Until very recently the steam turbine has in large sizes played its part entirely on an alternating current stage, and the particular advantages which this class of prime movers offers have not been available to any extent in direct current service. Apparently the difficulty has been electrical, for the design of armatures capable of withstanding the centrifugal force developed at the high peripheral speeds common in turbine practice and the production of commutators which will neither fly apart nor spark viciously at circumferential velocities of 5,000 to 6,000 ft. per minute constitute the essentially hard problems in the evolution of the turbo-generator. In some cases the matter has been settled by reducing the dynamo speed through gearing, but in outputs exceeding 300 KW. or thereabouts this method has not attained much popularity.

The direct current turbine has been needed for a long time in certain kinds of work, and the advent of machines rated at 2,000 KW. or upwards

is a real step forward. In every service where the plant is subjected to sudden variations in load the excellent economy of the steam turbine over a wide range of output is naturally one of the strongest arguments for its adoption. When the load variations are more gradual this point becomes of relatively less importance, as it is then a comparatively simple matter to operate the plant within its economical range by throwing in or out different units as the load changes. Of course in actual practice the question of keeping the engines at their efficient working points is often sadly neglected, and it is not uncommon in isolated plants to find one or two large units running on light loads with the smaller machines standing idle close by. This is no fault of the reciprocating engine, but it is clear that the cost of operation cannot be held down properly with such machines unless at least average intelligence is displayed by the attendants in their use.

It is not only in the isolated plant carrying a heavy load of electric elevators that the direct current turbine is certain to be useful. The small electric railway power station is a particular case in point, for in many of these installations the load factors are notoriously bad, and any relief which can reasonably be given is sorely needed. On a four car road covering perhaps ten or fifteen miles of highway it is next to an impossibility to maintain a good load factor throughout the day, and the expedient of installing an alternating current generating station with the usual high tension transmission line and rotary converter substations only increases the complication without radically improving the production economy of the main plant.

In a 2,000 KW. direct current turbo-generator recently under contract the guaranteed steam consumption at full load is 18 lbs. per KW.-hr. At three-quarters load this is increased but about 4.5% to 18.8 lbs.; at half-load the consumption is only 19.6 lbs., or practically 9% more than full load, and at one-quarter overload the steam consumption rises only 2.2% to 18.4 lbs. These figures are characteristic of good turbine practice, and are of course in no sense due to the fact that the turbine under consideration drives a direct current generator, but they are significant in the light of power station requirements on small and even medium sized roads. Given coal at $3.60 per short ton and an evaporation of 10 lbs. of water per lb. of coal burned, the fuel cost of operating this turbine at half instead of at full load is only about 30 cents per hour more than in the latter case.

On account of the small floor space occupied per kilowatt of capacity the direct current turbine has attained a wide usefulness in the work of train lighting, and the earlier machines were designed principally for that service. Their operating simplicity, adaptability to high steam pressures and low expense of attendance counted heavily in their favor in railroad circles, and there is no reason why the same advantages should not hold good in isolated plant work, particularly in cases where the cost of real estate is high. As yet little has been made public in regard to direct connected continuous current turbine units suitable for isolated plants, but with the development of large sizes for electric railway work it cannot be long before other fields begin to enjoy the results of these pioneer designs. The 500 KW. direct current turbine which has been more or less on the market for two or three years doubtless fills the requirements of some of the smaller roads, but it is only since the much larger machines have been brought to the attention of railway engineers and managers that the advance into the wider field has really begun. On the face of things the economy, durability, compactness and operating simplicity of the turbo-alternator should be repeated in the direct current outfit, and if the experience of the next year or two with the new electrical generators proves satisfactory, there is little doubt that the steam turbine will attain even broader usefulness than it enjoys at present. These are interesting days in motive power development, and the selection of a prime mover for a given plant is not to be made off-hand. With the gas engine attaining a brake horsepower hour on one pound of coal and the steam turbine branching into direct current practice, the reciprocating engine builders have a still harder task ahead to win out in specific cases where operating economy is the main point at issue. Fuel consumption is not the only thing, however, to be considered in most modern power plants, and the probabilities are that the development of prime movers in the next few years will not result in the extinction of present types, but will serve to clear up better than ever before the limitations and fitness of the different machines for specific kinds of work.

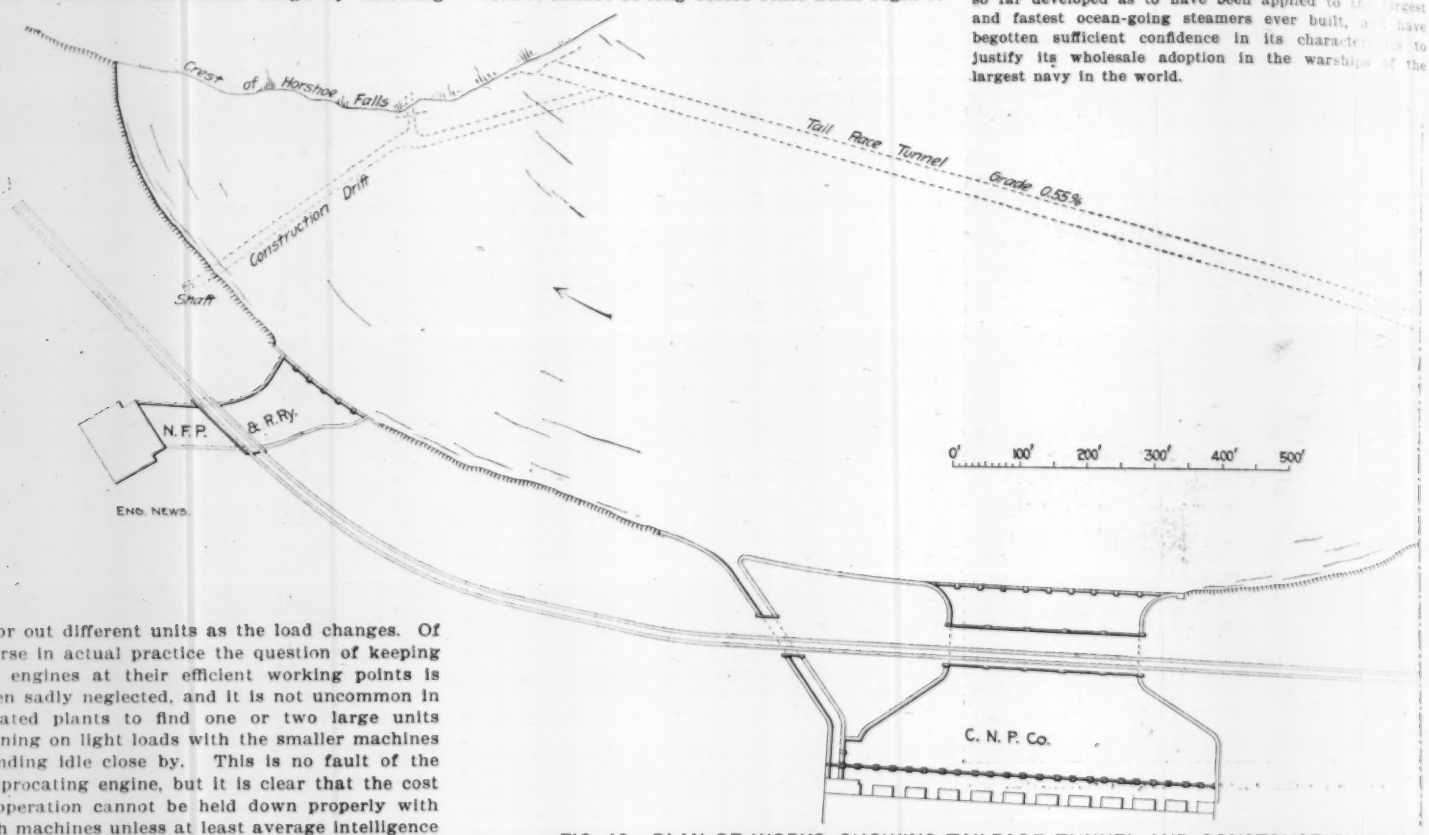


FIG. 10. PLAN OF WORKS, SHOWING TAILRACE TUNNEL AND CONSTRUCTION DRIFT.

TESTS OF RAILWAY-TRACK SPIKES, both ordinary and patented drive spikes and screw spikes, are to be made by Mr. R. I. Webber at the Engineering Experiment Station of the University of Illinois, Champaign, Ill. The power required to drive and withdraw the spikes, the resistance of the wood fiber to lateral thrust, and other tests, will be made with seasoned, unseasoned and treated ties of different kinds of wood. The spikes will also be driven into the solid wood and into holes bored in the wood.

MARINE STEAM TURBINE DEVELOPMENT AND DESIGN.*

By E. M. Speakman.

Few who saw the tiny experimental launch "Turbinia" steaming between the lines of warships at the Spithead Naval Review in 1897 would have prophesied that, in less than eight years, the steam turbine, then regarded with distrust even for electrical work, would have been so far developed as to have been applied to the largest and fastest ocean-going steamers ever built, and have begotten sufficient confidence in its character as to justify its wholesale adoption in the warships of the largest navy in the world.

First commercially adopted in the "King Edward" in July, 1901, there is now (September, 1905), about 700,000 I. HP. of marine turbine machinery built, or under construction, among which are the largest marine installations ever contemplated, the fastest mail steamers of all sizes ever built, and by far the fastest torpedo craft, while in many installations records have been made for economy of consumption, or saving of weight of engines.

The adoption of this type of motor—the Parsons type is referred to unless otherwise mentioned—has had a very marked and extremely valuable effect in shipbuilding circles, by causing a far more critical and retrospective view to be taken of ordinary machinery, and also, what is yet more important, necessitating closer attention to the question of propulsive efficiency.

The rapid development of the marine turbine has taken place entirely in Great Britain; a few experimental vessels have been built here and in Europe, but nothing has yet been done commercially. Now that the proportions of turbines and propellers can be determined with ample accuracy to enable very stiff guarantees to be made, both for speed and economy, a similar development may be expected in other countries.

DEVELOPMENT.

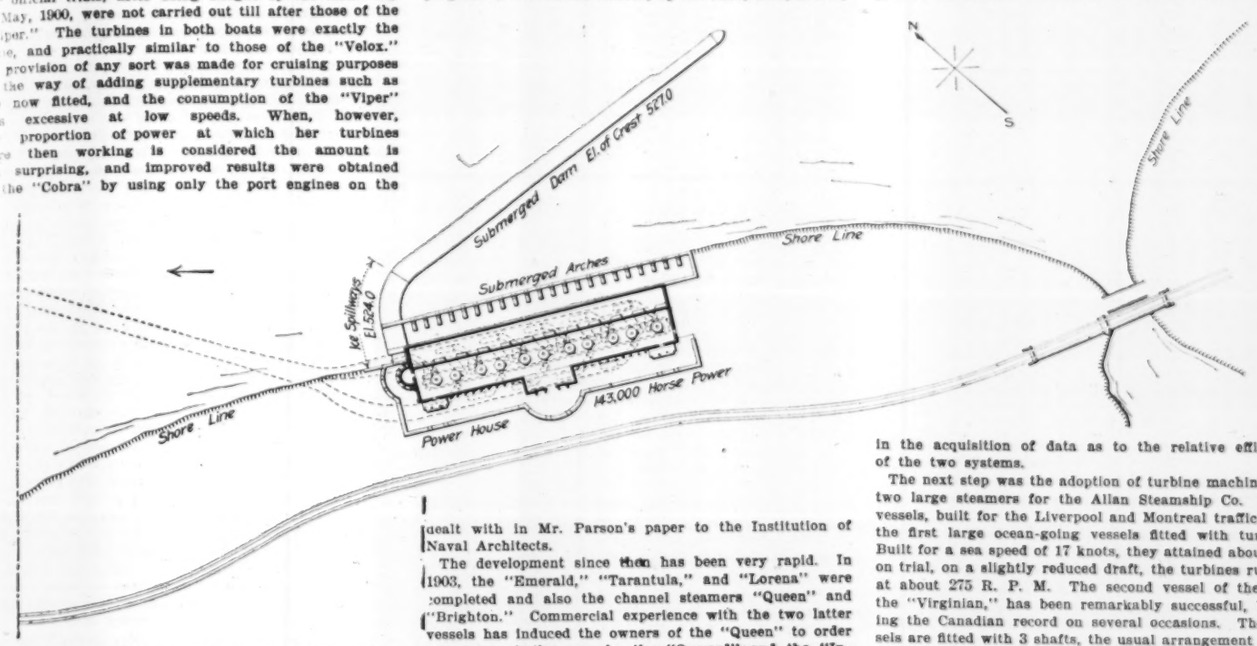
Compound steam turbines, on Mr. Parsons' well-known principles, had been made in small units since 1885, but it was not till 1894, that any definite attempt was made to apply them to ship propulsion.

Originally fitted with one radial turbine and one shaft, the "Turbinia" had a checkered experimental career before finally attaining, in 1897, a speed of about 33 knots, the ratio of $\frac{V}{\sqrt{L}} = 3.3$ being quite abnormal.

Public attention was first directed to this famous little vessel at the Naval Review, in that year, and soon after (in July, 1897), the British Admiralty was approached with the idea of getting turbine machinery fitted to a destroyer. The result was the order for the "Viper" early in 1898, the vessel being launched in September, 1899. Of the same size as the numerous 30 knotters then under construction, but of double the power, and being

*A paper read at the thirteenth general meeting of the Society of Naval Architects and Marine Engineers, held in New York, Nov. 16 and 17, 1905.

...y the second vessel fitted with turbines, the "Viper" ..., in many ways, one of the most remarkable ex...ples of naval architecture and marine engineering ever ...lt. Strictly speaking, the Armstrong Company had ...ed the order for the "Cobra's" turbines before the ...iper" was officially ordered, and with the former were ...ried out the greater share of the preliminary trials. ...n into and much damaged while lying at her pier ...the Tyne, the "Cobra's" completion was delayed, and ...official trials, after being bought by the Admiralty ...May, 1900, were not carried out till after those of the ...iper." The turbines in both boats were exactly the ...e, and practically similar to those of the "Velox." ...provision of any sort was made for cruising purposes ...the way of adding supplementary turbines such as ...e now fitted, and the consumption of the "Viper" ...s excessive at low speeds. When, however, ...e proportion of power at which her turbines ...were then working is considered the amount is ...ed surprising, and improved results were obtained ...the "Cobra" by using only the port engines on the



low speed trial and allowing the starboard ones to run idle. The "Cobra" was tried at about 440 tons displacement and the "Viper" at about 380; the results obtained being somewhat as shown in the accompanying table. (Table at bottom of page.—Ed.)

The end of both vessels was disastrous. The "Viper" after being in commission for some time was sent out for the naval manœuvers in 1901, and while scouting at high speed in a fog ran ashore and became a total wreck. The "Cobra" leaving the Tyne to go around to Chatham, broke her back in a heavy sea and sank. The loss of these vessels, and, with the latter, of several of the chief members of the staff of the Parson's Marine Co., considerably delayed the proposed comparative trials with other destroyers. By this time, however, the first commercial turbine steamer, the "King Edward," was in service. Laid down late in 1900, the trials were run in June, 1901, and the vessel put in service on July 1 that year. Her performance was watched with intense interest and to the excellence of the results obtained with her and the "Queen Alexandra," which followed during 1902, may be assigned the revolution in cross-channel boat machinery that has taken place in the last four years. Similar in general style, both vessels are remarkable for their light draft considering the power and the speed distinct minor improvements were made in the latter vessel, which, when out of commission between the seasons, has been largely used for experimental work.

After the trials of the "Viper" another destroyer, H. M. S. "Velox," of similar size was laid down, being launched in February, 1902, and in this vessel an effort was made to obviate the excessive consumption at low speeds by fitting two small reciprocating engines to the inner shafts. These small triple expansion engines were not reversible and added slightly to the weight, though they materially improved the economy up to 12 knots, above which they are disconnected. This is the only attempt hitherto made by Mr. Parsons to fit a twin system, though a similar arrangement in the "Caroline," built by Messrs. Yarrow, was tried in conjunction with Rateau turbines.

Meanwhile, the Admiralty, being naturally impressed with the success attending the "King Edward," and "Queen Alexandra," ordered two third-class cruisers—the "Amethyst" and "Topaze"—the former being fitted with turbines and laid down in January, 1903, the latter being fitted with the most modern type of reciprocating engines. The experiments to be carried out with these vessels were awaited with considerable interest. A 550-ton destroyer, similar to those of the new type laid down about 1902, was also ordered with turbine machinery, and several commercial vessels were commenced as soon as the performance of the "Queen Alexandra" had shown results similar to those of the "King Edward." The progress of the marine turbine, up till June, 1903, is fully dealt with in Mr. Parson's paper to the Institution of Naval Architects.

The development since then has been very rapid. In 1903, the "Emerald," "Tarantula," and "Lorena" were completed and also the channel steamers "Queen" and "Brighton." Commercial experience with the two latter vessels has induced the owners of the "Queen" to order two more similar vessels, the "Onward" and the "Invicta," while for the Newhaven and Dieppe service, the "Dieppe" is practically a duplicate of the "Brighton." The "Tarantula" and "Lorena" have been the subject of an official report by officers of the Navy Department, while the "Emerald" is noteworthy in that on her were carried out the experiments dealing with the number of screws per shaft, results being obtained which were afterward confirmed by experience in the "Turbinia," "Queen Alexandra," and "Queen."

These experiments were of considerable importance, and resulted in a change of ideas regarding turbine driven propellers. The "Emerald" was fitted with the usual arrangement of three shafts, the HP. turbine driving the center one which carried a single propeller, and exhausting into a low pressure turbine on each side, which drove the wing shafts. (Some economy of weight results from using a 3-stage turbine with an HP. and M. P. cylinder driving the two outside shafts, and the L. P. one the center, compared with this arrangement of 1 HP. and 2 L. P.'s; but the power of manœuvering ahead and astern on each side is not readily obtainable.) In the "King Edward," "Queen Alexandra," and "Queen," and, to begin with, the "Emerald" the wing shafts carried two screws on each, separated by about 2½ to 3 diameters. Considerable vibration occurred, due to the proximity of the forward screws to the hull, and as the suppression of these without other alterations led to no change in speed, a series of trials was made which determined the superior efficiency of single propellers. The improvement in overall efficiency which resulted has been continued by the adoption in other types of vessel of larger propellers and slower speeds of rotation, and further experience has shown the advisability of running at about the same revolutions with each shaft. The reason of this increase in propulsive efficiency is that the propeller efficiency improves far more rapidly with increase of size than the turbine loses; in fact, the economy of the latter remains constant over a very wide range of speed if designed for the same internal conditions.

The trials of the "Queen" in June, 1903, were attended by numerous eminent naval architects, of whom Professor Biles and his partner had under consideration at that time, the designs for four channel steamers for the Midland Railway Co. It is sufficient to remark here that of these vessels, two were built and engined by Messrs. John Brown and Messrs. Caird with the ordinary type of engine and an abnormally high efficiency obtained from them. The other vessels were engined by Messrs. Parsons, and all four were minutely described in Engineering, October, 1904, and in Mr. Gray's paper to the Institution of Naval Architects in 1905. The comparative trials of these vessels, representing the most modern practice in channel steamers, formed an important step in the acquisition of data as to the relative efficiency of the two systems.

The next step was the adoption of turbine machinery in two large steamers for the Allan Steamship Co. These vessels, built for the Liverpool and Montreal traffic, were the first large ocean-going vessels fitted with turbines. Built for a sea speed of 17 knots, they attained about 19½ on trial, on a slightly reduced draft, the turbines running, at about 275 R. P. M. The second vessel of the pair, the "Virginian," has been remarkably successful, breaking the Canadian record on several occasions. The vessels are fitted with 3 shafts, the usual arrangement of the HP. and two P.L. turbines being adopted. The high-pressure turbine is about 5 ft. 6 ins. in diameter, and the low pressure about 8 ft., each turbine carrying about 80 rows of blades. The trials of the first vessel did not take place until April, 1905, and though the largest vessels in the world had previously been commenced, turbine machinery being adopted, the results obtained went a long way towards assuring naval architects of the eventful success of the Cunard vessels.

Earlier in 1903 than either of these two important installations, a fast channel steamer for the Stranvast and Larne service had been ordered, followed almost immediately by the commencement of a fast light-draft vessel for the Union S. S. Co., of New Zealand. This latter vessel, the "Loongana," left the Clyde in August, 1904, and ran to Port Said without a stop—3,350 miles at 16 knots—completing her voyage to Melbourne, Australia, from Glasgow, in 30 steaming days. The average speed over the whole distance was about 16.5 knots, at which the coal consumption was about 1.6 lbs. per I. HP. per hour, the full speed being over 20 knots.

The most important feature in the development of marine turbines has, undoubtedly, been the decision of the Cunard S. S. Co. to adopt turbines for the new vessels of that line. For some time it had been evident that new mail steamers would be required, though for many reasons the date of ordering them was postponed again and again. In September, 1903, however, the Cunard company appointed a commission which consisted of seven gentlemen of very high standing in the profession, including representatives of the Admiralty, the Board of Trade, and of the manufacturing companies concerned, to investigate this question of design, and especially the type of engine to be adopted. At this time, the "Caronia" was being built by Messrs. John Brown for the Cunard Company. She is fitted with quadruple expansion reciprocating engines driving twin screws, and soon after the formation of the committee, and long before their report was complete, a turbine-driven sister ship—the "Carmania"—was ordered. This vessel, of 21,000 HP., is similar in all respects to the "Caronia," except for her engines and propellers. Her three shafts revolve at 185 R. P. M., driving 14 ft. propellers, the turbine arrangement being the usual three-cylinder one. These vessels will probably form the final stage of comparison between the two types of engine for first-class ocean-going vessels, completing the invaluable series of comparative trials that have been carried out in various types of vessels—destroyers, cruisers, channel steamers, intermediate steamers, and, finally, in these Cunard vessels, of first-class mail boats.

The Cunard Commission report has been treated as confidential, and rightly so. Their investigations were most thorough and embraced very careful trials and experi-

"Viper."	Speed.		Equivalent I. H. P.	Mean R. P. M.	Total coal burnt, lbs. per hour.	Coal per I. H. P. hour, lbs.
Full power, 13-7-1900 (1 hour)	37.113	Max.	13,000	1,180	34,500	2.61
	36.585					
3 hours, F.P.C.C., 31-8-00	33.83		10,300	1,050	25,700	2.49
3 hours, official trial	31.118		8,350	950	19,800	2.38
12 hours, slow speed trial	15.		750	450	3,000	4.03
"Cobra."						
Port engine only	15.0		850	550	2,750	3.23

ments, not only on ships and models, but on details of construction, and it would be hard to exaggerate the thoroughness with which these vessels—the largest in the world—have been designed. The tremendous increase in power necessary over anything that had been previously attempted, involved very great difficulties in the design of reciprocating engines. Twin screws were practically impossible, the dimensions of cylinders and shafting being prohibitive, triple screws necessitated a very awkward arrangement combined with many (and us-

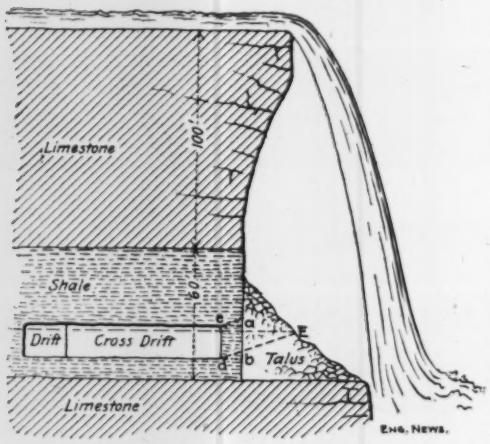


Fig. 12. Sketch Showing Conditions at Opening of Construction Drift Behind Falls.

ually uncriticized) experimental features. Having regard to the design of turbines and the question of propeller efficiency, a four-shaft arrangement offered the best solution in this particular case.

Considerable criticism has been leveled at this decision, and the subsequent wholesale adoption of turbines in the Royal Navy; but it must be remembered that the gentlemen responsible for it in each case were those who had complete access to all the data available on the whole subject, and that it was no case of competition, but the result of an earnest and deliberate investigation, in both cases by men most experienced in both types of engine, to decide which one was best suited to their own requirements.

Among the investigations that were carried out for determining the relative efficiency of the two systems, were trials made on the turbine steamer "Queen," and the other vessels running on the Dover-Calais Service, and also on the "Brighton" and "Arundel" on the New Haven and Dieppe Station. These tests were amplified by data obtained from the Clyde turbine steamers and from two large destroyers tested by the Admiralty.

These Cunard installations, of about 68,000 I. HP. each, are divided into two complete engines, of which the high-pressure turbine of each set drives the outer shaft, while the low-pressure, with which is incorporated the astern turbine, drives the inner shaft on each side of the vessel. The high-pressure turbine drum is about 9 ft. in diameter, carrying about 150 rows of blades, while the rather larger L. P. drum carries about half that number. The distorting effect of heat on the shape of cylinders of such immense size has necessitated very special design, but the care and skill with which the engineers responsible for the manufacture have proceeded, can only result in well-deserved success.

During 1904, early in which the decision to adopt turbine machinery in these vessels was announced, several orders were placed for vessels with turbines for all types of fast steamers, while the publication of the comparative results obtained from the "Amethyst" and "Topaze" was second in interest only to the Cunard installation.

In 1905, the Allan turbine steamers were tried, the new vessels for the Dover-Calais and Dieppe services commenced running, and the S. S. "Viking," a pleasure steamer of 23.5 knots trial speed put in service, while three vessels of 23 knots and of 9,000-10,000 HP. each, were ordered by the Great Western Railway Co., and during the latter half of the year the orders for turbine machinery have been very numerous.

Another important decision, and one largely influenced by the report of the Cunard Commission and the splendid performance of the "Amethyst," was that of the British Admiralty to adopt turbine machinery for its vessels. Triple shafts are adopted for the 26 and 33-knot destroyers, while a quadruple-shaft arrangement is to be fitted in the battleships and large cruisers.

It will possibly be of interest to analyze the reasons for this rapid adoption of the steam turbine; the keen competition in Great Britain may have influenced it slightly, but for any motor to start commercially in July, 1901, and, in March, 1904, to be adopted for vessels such as the new Cunarders, is prima facie evidence of some striking inherent excellence.

TURBINES COMPARED WITH RECIPROCATING ENGINES.

While many of the advantages claimed for the turbine over piston engines are inseparable from the use of such a motor, others are largely dependent on excellence of design, and the prescience with which these claims were made in the days of the "Turbinia" and "Viper," has been fully justified in the light of later experience. These features are discussed in detail, and may be summarized as follows:

1. Increased economy in steam consumption.
2. Increased speed owing to considerable reduction in weight of machinery and smaller steam (and coal) consumption.
3. Complete absence of vibration from main engines.
4. Reduced cost of attendance and overhauling.
5. Reduction in oil and stores used.
6. Reduction in space occupied, if desirable.
7. Reduction of propeller diameter, which permits—
   1. For same draft, increased immersion, and prevents racing.
   2. For same immersion, a considerable reduction in draft.
8. Lower center of weight of engines and reduced weight necessary. There are, however, two striking advantages which are seldom or never quoted for the turbine, and these are:
9. The adaptability of turbine machinery for powers and speeds at which piston engines become constructionally impossible on account of weight, or of inertia stresses, and also on account of cavitation.
10. The property of maintaining the original economy on account of the absence of rubbing surfaces on which economy depends.

The difficulties originally found in applying turbines to marine propulsion were chiefly in the design, and are now largely overcome.

They are:

1. The arrangement and design of propellers for high speeds of rotation.
2. The inefficiency of turbines at low speeds.
3. Reversing and manoeuvering qualities.

Due to the adoption of turbines in place of piston engines in ships of similar design, far more attention has been directed in the last three years towards the actual economy of the main engines as opposed to that of the complete installation, and the numerous trials made for obtaining the actual steam consumptions show that, under the same conditions, reciprocating engines, of equally careful design, are only slightly more economical than turbines when working below about 60% of the vessel's full speed (that is, say 12 knots for a 20-knot ship) while above this the turbine is superior. Ample and reliable steam consumption data for all classes of warships is now available from trials conducted by the British Admiralty, who have also carried out careful comparative tests on cruisers and torpedo-boat destroyers, exactly similar but for their propelling machinery, for the purpose of determining the relative efficiency of the two systems. Similar experiments have been carried out with channel steamers in a very comprehensive way, and in all cases the actual trials of the ships have been supplemented by elaborate tank experiments. T[illegible] result of these investigations has been the adoption of [illegible] Parsons steam turbine for all classes of British w[illegible]ips.

The cruisers tested were the "Topaze" and "A[illegible]yst," of 3,000 tons. Fitted with turbines, the "Ame[illegible]" obtained a maximum speed of 1.5 knots more [illegible] the "Topaze"; for the same steam consumption, [illegible]speed of the "Topaze" was 21 knots against the "A[illegible]st's" 23, or for 22 knots the consumption per unit of [illegible]r in the "Amethyst" was 13.8, and in the "Topaze[illegible] lbs. The progressive trial results are shown in Fig[illegible].

Carried out with great care, and corroborated [illegible] the similar results obtained from the two sister ship[illegible] the "Topaze," these long-desired experiments on [illegible]milar ships, running under similar conditions, did n[illegible] than demonstrate the superior economy of the turbi[illegible] full power. They showed that down to 14 knots [illegible] turbine was more economical, and that below this [illegible] the difference in favor of the reciprocating engin[illegible] by no means as large as had been supposed. In [illegible]with the auxiliary exhaust steam being passed thro[illegible] the turbines, the economy is better above 10 knots.

Similar results were obtained from the trial[illegible] of the Midland Railway steamers, which, unlike the "Amethyst," were not fitted with cruising turbine[illegible]. The greater economy of the turbine vessels was very marked at high speeds, and only ceased below 14 knots.

The question of economy is very important. It is, probably, the crucial point in considering the adoption of turbines, and even if the machine possessed no other advantages, economical results such as have been obtained undoubtedly entitle it to careful consideration. Fig. 2 gives the steam consumption per I. HP. of H. M. S. "Amethyst," compared with that of other warships over a wide range of speed. Actual steam consumptions of merchant vessels run at low powers are almost impossible to obtain, but seeing that naval engines are designed to be most economical at about 80% of full speed, and that at 50% there is such a marked rise in their consumption, there can be little doubt that the performance of merchant engines, designed for maximum economy at full power, would be much the same at low speeds as that of the warships. There has been a tendency, due possibly to a lack of data, to imagine that the consumption of ordinary engines at low speeds was not so great as recent trials have shown it to be.

Fig. 3 gives the total consumption of the "Amethyst," and "Topaze" plotted on horsepower, while Fig. 4 gives a similar diagram for two destroyers tried. Fig. 5 gives the total amount of water used at various speeds for the Midland Railway steamers. Similar results to these were obtained with the Brighton (turbine) when run against the sister ship "Arundel," the efficiency increasing from about 6% at 16 knots to 12% at full speed. I do not think I can say anything to add to the convincing nature of these diagrams.

In considering the relative economy at low speeds, it is well to remember what these speeds actually are. The standard low power trials in the English navy are run at one-fifth of full power, which corresponds to [illegible]% of full speed, and only very rarely in large vessels are they extended below this. Torpedo craft are tried [illegible]e-

FIG. 13. VIEW INSIDE TAILRACE TUNNEL AT JUNCTION WITH BRANCH TUNNELS.

...n 45 to 50% of full speed; their normal service cruis- ...speed is between 14 and 15 knots. For long voyages, ...t 55 to 65% is a fair average, and at such speeds ...e is little difference in consumption between the two ...s of engine. As an instance of typical cruising ...ds, the Japanese battleships steamed out from Eng- ...d to Japan at an average of 54% of full speed; while ..."Oregon's" famous trip was made at about 66%. H. ...S. "Terrible's" recent voyages to China and back

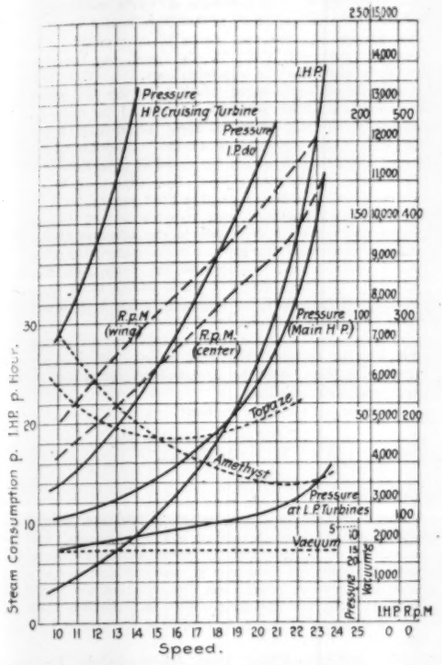


Fig. 1. Diagrams of Speed and Steam Consumption Obtained in Progressive Trial Results of Turbine Cruisers.

from Portsmouth were made at 57%, and the British battleships which recently returned from China made the trip at about 65% of full speed. The speeds kept up in the Atlantic manoeuvers of the British fleet in 1903 were very high—being at over 80% for several days, but on the other hand, the speeds used when blockading, as for instance outside Port Arthur, are necessarily very low. Many similar examples can be given, and if more data is required, the consumptions in Fig. 2 can be plotted on percentage I. HP. instead of speed, when it will be seen that the superiority of the turbine disappears only below about 15% of the maximum I. HP.

II. The reduction in weight of machinery is a feature of turbine installations closely allied with that of constructional possibilities. As for instance, in the "Turbinia" where the weight of turbines and shafting was 3.65 tons, or only 4.08 lbs. per I. HP. Of similar power, but for a lower speed, the Rateau turbines of the "Caroline" weighed 8.6 lbs. per I. HP.

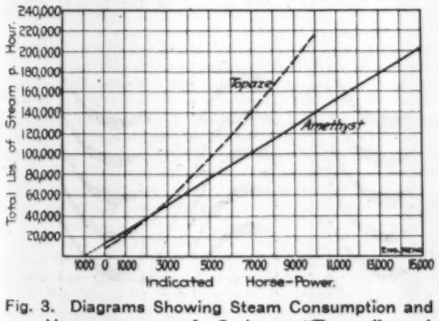


Fig. 3. Diagrams Showing Steam Consumption and Horse Power of Cruisers "Topaze" and "Amethyst."

In the "King Edward," the weight of engines and condensers, shafting and propellers, including the air and circulating pumps which were driven off the L. P. shafts, was only 66 tons, or 42 lbs. per HP., a gain in weight similar to the 70 tons saved by adopting turbines in place of reciprocating engines in the "Lorena," also of 3,500 I. HP.

In the channel steamers, a fair weight for the respective systems may be taken as about 80 lbs. per I. HP. for piston engines against 60 for the turbine, for all weights of actual propelling machinery aft of the forward engine room bulkhead.

The following figures show the machinery weights of the Midland Railway Co.'s steamers:

Vessel.	Engine.	Total weight.	Boilers.	Engines.	Shafting and Propellers.	I. H. P.	Lbs. per I. H. P.
		Tons					
"Antrim" and "Donegal"...	R	730	460	215	65	6,500	96.6
"Londonderry"	T	575	390	160	25	6,500	63.7
"Manxman"...	T	655	460	195		8,000	54.6

That is to say, the weight of the reciprocating engines of the "Antrim" (whose builders, Messrs. John Brown,, are among the most experienced channel boat designers that there are), was about 78% more than that of the turbines of the "Manxman," and 52% more than that of the "Londonderry's." Certain hull weights being saved in keelsons, shaft bossing, etc., in the turbine steamers, brought the total saving in weight to 6% of the displacement of the entire ship. In comparing the "Antrim" and "Londonderry," it must be remembered that

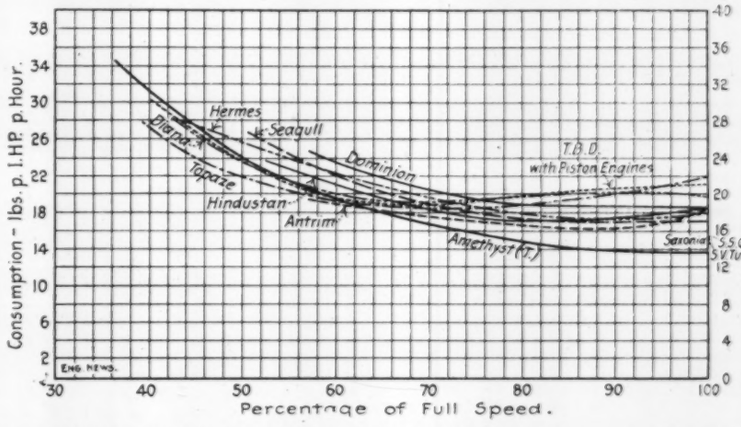


FIG. 2. DIAGRAM SHOWING COMPARATIVE WARSHIP STEAM CONSUMPTIONS AT VARIOUS PERCENTAGES OF FULL SPEED.

the boiler pressure in the former was 200 lbs., against the latter's 150; that is, if the "Antrim's" had been 150 lbs. too, the boiler weights would have had to be still larger in order to cope with the increased consumption, while the engine weights would have been greater, too, due to the larger cylinders necessary with the lower pressure.

In the "Amethyst" and "Topaze," the total machinery weights were kept the same, in spite of a slightly lesser weight of engines only in the "Amethyst." The total weight of machinery for each vessel was practically 535 tons, on which the turbines developed 14,000 HP., and the piston engines only a bare 10,000. The bunker capacity in each vessel is about 750 tons maximum, and Fig. 2 is a fairly accurate guide to the relative radius of action.

Comparing the "Viper" with the reciprocating engine destroyers of the same dimensions (viz.: 210 ft long x 21 ft. beam), the turbine propelling machinery of 12,000

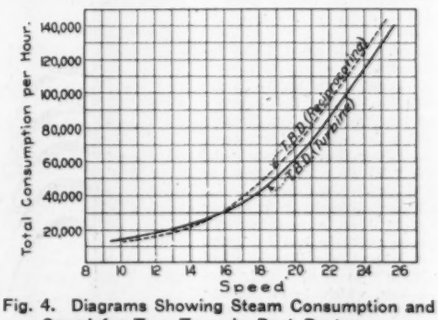


Fig. 4. Diagrams Showing Steam Consumption and Speed for Two Torpedo Boat Destroyers.

HP., with condensers and pumps, shafting, and propellers weighed about 73 tons, while the same details for the 6,000 HP. piston engines were rather over 80 tons. A larger destroyer of 9,500 HP., designed for 33 knots—H. M. S. "Express"—had about 115 tons devoted to this, making the weight per horsepower 27.1; the 30 knotters being about 30 lbs, and the "Viper's" 13.6. To compensate for the lighter engines, various other portions, especially in the stokehold, were increased in weight, and the total for engines and boilers, with water and auxiliaries connected with propelling, was about 30 tons more than that of the 30 knotters, and 20 tons less than that of the "Express," whose actual speed was 31.0 knots.

In view of the proposed 36 knotters for the British Government, these figures are of interest; of twice the power of the piston engines in vessels of the same size and shape, the "Viper's" engines weighed 8% less and occupied the same space. Reciprocating engines of that power could not have been made for that speed (1) on account of weight required affecting the displacement, and of this reacting on the power necessary, and (2) on account of propeller difficulties, due to cavitation, limiting the speed of rotation, which would have affected the weight still more. When the power is increased yet further, the inability to construct piston engines becomes even more apparent, and it is obvious that the peculiar property turbines possess in that their size is affected only by the revolutions and the pressure, and very slightly by the power developed is extremely valuable. When, as in these 36 knotters, the proposed power is 28,000, equal to the "Lucania," or twice that of the "Baltic," recourse must be had to the turbine.

III. The complete absence of vibration from the main engines has many advantages. The deleterious action on the structure of the ship, the discomfort to passengers, the malicious affect on gun fire, and in many cases the impossibility of running the engines at their proper speed due to vibration, have resulted in treatises on engine balancing by numerous very talented authors. When an evil necessitates such notice as has been bestowed on it—and the transactions of this society bear witness to the difficulty of eradicating it—it must be fairly serious. Unless a turbine is balanced it will not run properly. It was found on some of the early vessels fitted with multiple screws that the propeller vibration was very objectionable, but this was chiefly due to the high speed and proximity of the forward screws to the hull.

The recent tendency to use slower speeds and only one screw per shaft, and that one considerably further from the hull than in ordinary practice, has entirely eradicated this evil. Experiments made by Schlick on the "Deutschland" show that the material effect on balance that the varying intensity of the wake possesses is very

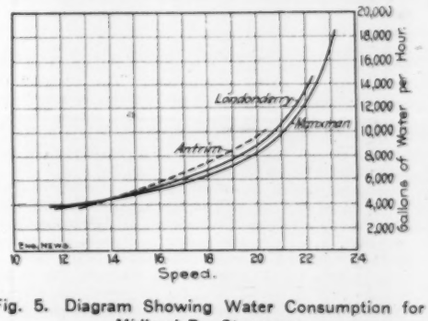


Fig. 5. Diagram Showing Water Consumption for Midland Ry. Steamers.

marked. This effect is the only one likely to cause vibration in turbine work, but the smaller diameter on screws used means a less varying intensity over the disk area than is the case with ordinary propellers.

IV. The reduced cost of attendance and overhauling that can be obviated amounts to a larger proportion. When once adjusted and closed up, the lack of reciprocating motion, and the great reduction in the number of bearings, reduces both the attention necessary and the quantity of oil required. Supplied under a pressure of 6 to 8 lbs., large oil coolers are necessary on account of

the cylinder heat being communicated to the bearings; these may run at a temperature of 110° to 140° F., and ample oil must be supplied. It can be used, however, again and again, the bearings all being enclosed, and, as an instance of oil economy, the "Queen Alexandra" may be mentioned, her consumption being under one barrel

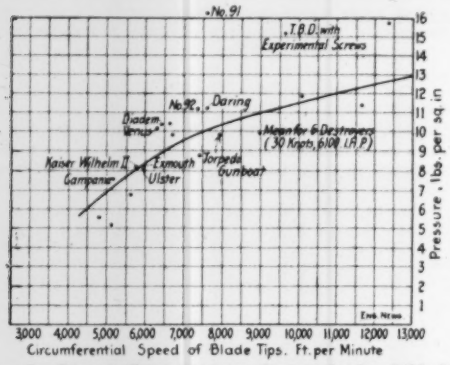


Fig. 6. Thrust Pressures per Square Inch of Blade Area Corrected to 12 Inches Immersion.

for the whole season, say 4 or 5 months. Similar instances are obtainable from the other vessels.

Slight deficiency of good manoeuvering qualities in the early turbine steamers has been condemned by some, but it has been due in almost all cases to the amount of power provided for astern working. In more recent vessels, where a larger proportion has been supplied, the manoeuvering qualities have been stated by many competent authorities to be excellent and quite equal to twin screw vessels with reciprocating engines, and under certain circumstances to paddles. The astern speed of the "Queen" was 13 knots and this has been increased to 15 in the sister ships on the same service, and to 16 in the "Princess Elizabeth." Careful manoeuvering trials were carried out with the "Dieppe," and also with the Admiralty vessels, the "Amethyst" being tried against her sister ship, "Sapphire."

The reversing turbines are incorporated with the L. P. spindles and revolve idly in the exhaust casing when the engines are running ahead. It must be noticed that there is no further complication involved by this, only a slight addition to the length of the turbine and a few more rows of blades. It is usual to make this turbine of the same diameter as the high pressure one and to obtain the power on smaller dimensions, slightly reducing the efficiency. The real inferiority is in manoeuvering from rest, especially from alongside a dock wall, but judging from the reports which have occasionally been made one might be led to believe that nothing worse than inward-turning ordinary screws could be devised. Against this defect may be set the fact that the reduced diameter decreases the risk of fouling the blade tips.

Reduction in space occupied may be of comparatively small moment in vessels taxed on under deck capacity minus a liberal allowance for engine space, but reduction in overhauling cost in large steamship lines is gladly welcomed, and the admitted reasons for the bold application of turbines in the Allan liners are absence of vibration and reduction of overhauling costs. When, as in the "Queen Alexandra," turbine covers are not lifted for two years, repair lists will be enjoyable reading compared with the present voluminous documents.

The great reduction in number of parts in an engine cannot fail eventually to reduce manufacturing cost.

Regarding working cost and overhauling, no increase of consumption results in a Parsons type of turbine due to length of service, such as occurs in reciprocating work from wear of valves and pistons. The machine once made and closed up retains its original economy (provided there is no accident, of course) within limits of errors of observation.

These several features result in a considerable gain in commercial efficiency.

Assuming that it is settled that a battleship of 20,000 HP. is to be engined with turbines. The economy (compare "Amethyst" and "Hindustan" or "Dominion") will be better, and while the saving in weight will perhaps not be as marked as in the channel steamers, it will at least be 10% for the engines and shafting. As to boilers, the reduced consumption enables greater power to be obtained from the same weight, or the same power from less weight, and the same arguments apply to the coal supply. In the Atlantic manoeuvers, in 1903, extensively carried out by three large British fleets, an engine-room record of all mishaps and repairs necessary was kept. Of 12 first-class battleships and cruisers materially inconvenienced by engine defects (many of them very minor, but still inconvenient), in 8 these defects were in portions that could not occur in turbine installations owing to their absence. (Twelve vessels may seem a large number, but seeing that 70 large vessels, apart from torpedo craft, were engaged, it is a small proportion.) The height of the armored deck can be reduced owing to the reduced height of engines; the reduction in size of propellers is an appreciable advantage when draft of water is a limiting consideration in the design of warships, while in torpedo craft the tiring effect of vibration on the crew, which is so well known where piston engines are concerned, is entirely eliminated.

The adoption of turbine machinery and higher speeds in the large warships of the Royal Navy has been accompanied by material advantages on these lines, but what value these assume in the eyes of naval authorities in this country will, I trust, be indicated in the discussion.

DESIGN.

The determination of the various dimensions of turbines and propellers to ensure a given result involves considerable calculation, but may be made with great accuracy.

The primary step is the estimate of highest rotary speed suitable in order that the turbine may be made as small as possible for any given efficiency, the calculation of propeller dimensions necessitating considerable experience of high speed propeller design, and more especially of the considerations involved in the efficiency of propulsion. The main difficulty in applying turbines to marine propulsion is this question of the most suitable design and arrangement of propellers and turbines in order that their combined efficiency may be at least as good as it is with ordinary machinery.

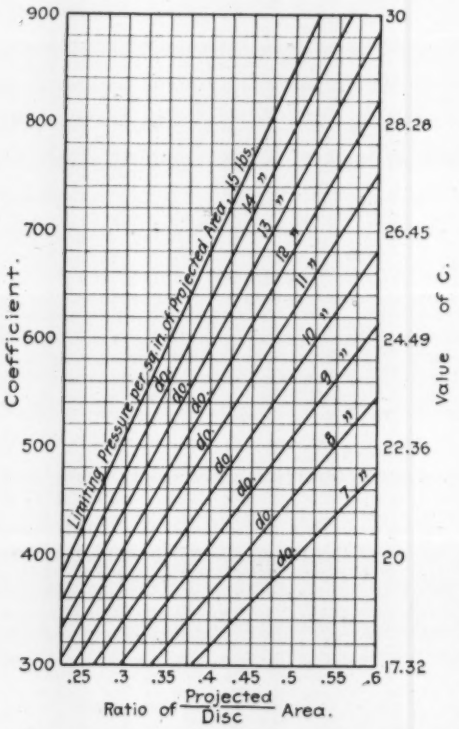


Fig. 7. Diagrams of Coefficients for Turbine Propellers.

Some years ago, prior to the trials of the "Turbinia," the phenomenon of cavitation was found to occur in propellers driven at very high speeds. It is due, partly, to excessive peripheral speed of blades, and partly to excessive thrust pressure per square inch of projected blade area. The speed limit beyond which cavitation appears is about 12,000-13,000 ft. per minute, while the pressure limit varies considerably with the shape and section of the blade, but is between 10.5 and 12 lbs. per sq. in. at 12 ins. immersion of tip. Beyond this, there is a very rapid drop in propeller efficiency due to increased slip, and to obviate this sufficient blade area is absolutely necessary, which, in conjunction with various practical proportions, limits the rotary speed. Much higher ratios of projected to disk area than were ever attempted with ordinary propellers are used in turbine works in order to reduce the diameter as far as possible, many vessels having ratios of about 5. The pitch ratio adopted is likewise much finer than usual in order to increase the revolutions, being from .8 to 1.0 in vessels between 17 and 25 knots; but for very high speeds, nothing under 1.0 should be used. The "Turbinia's" was about 1.3, and the channel steamers .9.

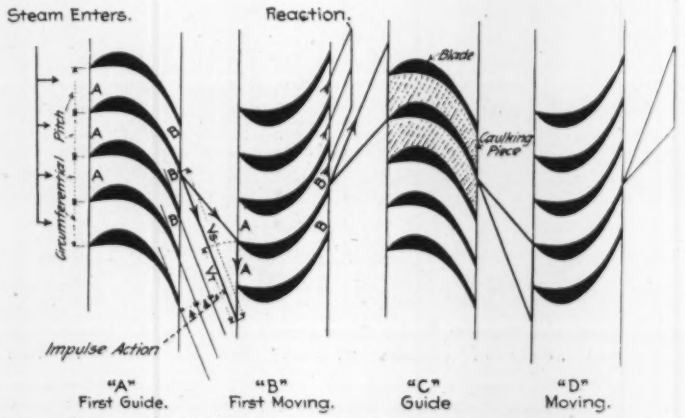


FIG. 8. DIAGRAM OF STEAM ACTION ON BLADES OF PARSONS TURBINE.

The slip varies considerably; in some vessels it has been brought quite low, down to 15%, but more generally it is between 17 and 27% ("Amethyst," 17% at full speed; "Manxman," 24%; "Viper," about 28%.

The tip speeds that have been used reached a maximum in the "Viper's" 12,350; the "Amethyst" was about 10,100 on the wing screws, and the "Londonderry" 1,700. These are all very high, but many turbine vessels have not exceeded 9,000, which is quite in line with ordinary destroyer work. The pressure at which cavitation commences is also variable; probably it begins at about 10 lbs. per sq. in., and may reach 13 or even 14 lbs. without any abnormal effect on the speed, but the slip will be very high and the efficiency low.

Exhaustive analyses of trials made by the author go to show that this pressure has varied in reciprocating engine work from 5 lbs. to about 10, averaging approximately, when corrected to 12 ins. immersion, 7 lbs. for every 1,000 ft. per minute tip speed of propeller. (Fig. 6.) In turbine work, about 10-12 lbs., according to service of vessel will be found to give good results.

This pressure is the mean pressure per sq. in. of projected blade area, and is due to the effective thrust. It follows, then, that the greater is the propulsive efficiency for a given I. HP. the greater the blade area required will be. The best shape of blade seems to be the symmetrical circular one, as shown in Figs. 2, 3 and 4, but it is still undetermined.

I have advised the following formula for giving the diameter of turbine propellers direct, but it is obvious that much care must be bestowed on the design to obtain the best results.

Diameter of propeller in feet:

$$= \sqrt{\frac{\text{Effective thrust in lbs.}}{\text{Coefficient.}}}$$

$$= \frac{\sqrt{\text{Thrust}}}{c}$$

The coefficient is a compilation of pressure, area, ratio, and 144, and, on extracting the square root, becomes about 24 to 30 (see Fig. 7), these values covering turbine practice the formula is, however, perfectly available for ordinary work, but the value of the coefficient is much less, and the square root only reaches about 16-21 on account of the reduced ratios of projected to disk area.

The effective thrust must be accurately known if the steam balance of the turbine is to be good, but it is a difficult subject and involves much reference to tank results.

The diameter of the propeller, and from this the pitch, being obtained, the revolutions can be worked out and the turbine dimensions then arranged.

Assistance from tank work is not only extremely helpful, but very necessary in many cases, especially for large vessels, for not only does knowledge of effective power materially assist in the design of propellers, but tank experiments alone will determine the best shape of hull. Many of the members of this Society will be conversant with the great improvements made in the stern lines of the large German mail steamers due to tank trials, and there is no doubt that in the design of the new Cunard vessels, it would have been a far less easy matter to determine the best shape of afterbody, and especially of the shaft bossing, if the data from copious tank experiments had not been available. The conditions regarding the application of triple screws have been quite modified with the smaller diameters employed with the turbine; decreased augment of resistance compared with twin screws, is found to accompany their application, due largely to the greater distance from the hull and the largely reduced disk area, whereas with the larger diameters usual in ordinary work the reverse is the case.

Regarding the actual arrangement, it is hard to generalize. Where possible, three screws seem to give the most satisfactory results in fast vessels, both for turbine and propeller efficiency. To enable higher revolutions

to be obtained and to reduce the size of cylinders necessary, four shafts may be used, as in the large Cunarders, but such a course adds to the complexity, though diminishing the constructional difficulties encountered in cylinder design. An arrangement of two shafts has only been attempted in one small yacht, and is not to be recommended for Parsons turbines; it is, however, doubtful if it is possible to adopt this efficiently in large vessels with any present design of turbine. Four shafts are practically necessary in large naval work but for smaller cruisers and torpedo craft there may be

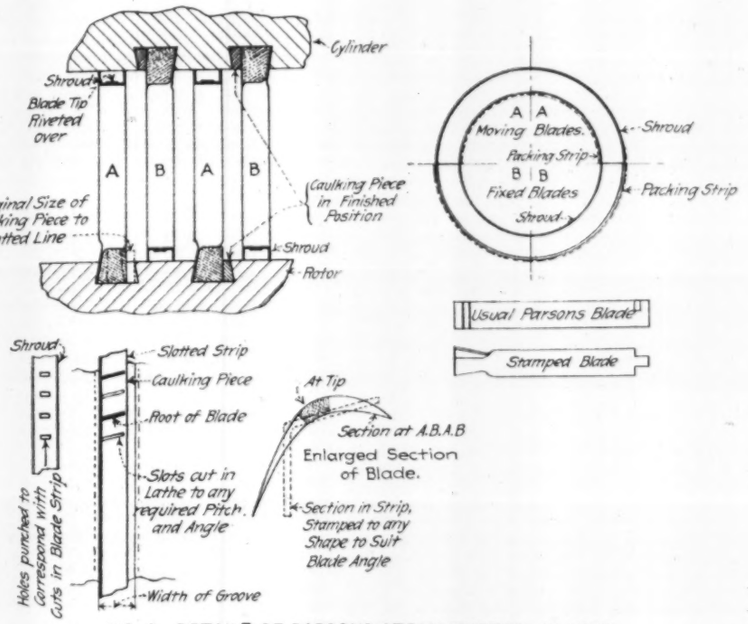


FIG. 9. DETAILS OF PARSONS STEAM TURBINE BLADES.

used—it is largely a matter of judgment according to circumstances.

Except in rare cases, where, to obtain higher revolutions and consequently less weight, some economy may be sacrificed and two screws used, only one propeller per shaft should be adopted.

Before leaving this subject, it may be as well to impress on those undertaking such designs, that while excellent results can be and have been obtained with this system of propulsion, it is only by very careful attention to the design and arrangement of propellers for efficient working it is impossible to assume revolutions and later on to design a propeller to suit.

The determination of the details of blading arrangements to secure the best results also necessitates considerable practice; there are few formula for guidance, such as are found in reciprocating engine work.

The general features of the design and the action of the steam in the blades of a Parsons turbine is, probably, well known to most of the members here. The total expansion of the steam is approximately adiabatic, and is subdivided into a number of steps, in each of which is maintained a certain dynamic relationship between the steam speed and that of the vanes. Each stage consists of a ring of stationary blades, which give direction and velocity to the steam, and a ring of moving blades that immediately convert the energy of velocity into useful torque. The total torque on the shaft is due to the impulse of steam entering the moving blades, and to a reaction as it leaves them, this process being repeated throughout the turbine.

The best relationship of steam speed and blade speed is largely a matter of opinion, and equally good results have been obtained with wide differences. Probably little is gained by departing in any way from the best theoretical value.

The vane speed VT is, like many other things, provided that the number of rows of blades is correct, a matter of convenience and is modified by experience; wide differences in this also can be made without tangibly affecting the efficiency. Assuming a speed, the diameter of the turbine is found from the formula:

$$\text{Diameter}'' = \frac{\text{Blade velocity in ft. p. sec.} \times 228}{\text{R. P. M.}}$$

The velocity acquired by the expansion of steam (= VS) may be found by calculating the B. Th. U. drop between the two pressures, whence,

$$VS = 223\sqrt{\text{B. Th. U.}}$$

The ratio of blade speed to steam speed being settled, the drop at each row may then be determined, which will give the number of rows of blades required, since the initial and terminal working pressures are known.

$$\text{No formula such as } \frac{\text{P. L. A. N.}}{33000} \text{ exists for determin-}$$

ing the main dimensions, but experience has shown that there are various formulas which can be arrived at from past practice, which will give a very suitable combination of dimensions. Such methods are the result of long and costly experiments, and it is scarcely surprising that builders should forbear to publish them.

The blade velocity adopted in practice varies largely according to the class work; generally it is much lower in marine work than with the high revolutions that are adopted for generators in electrical work. While that for marine turbines can barely exceed 200 feet per second as a maximum, without great sacrifice of propeller efficiency, it is more usual to adopt a far lower speed, say 100 to 140 feet per second. The Rateau and Curtis types of turbine require far higher velocities, the former about one and one-half times and the latter at least twice these speeds, and in marine work it is almost impossible to obtain them.

The blade height are made variable to allow for the expansion of the steam and the desired adjustment of velocities throughout the turbine necessitates intricate calculation, involving more space than is at the author's disposal.

The width and pitch of the blades are partially arbitrary and, to some extent, a matter of strength and convenience. Ample longitudinal clearance can be allowed, varying in practice up to ¾" with large blades, but the tip clearance is more important, and must be made as fine as possible. The blade tips are usually ground up and their diameters made accurate to thousandths of an inch; the clearance depends largely on temperature and diameter, and varies in amount from the thickness of a dime to that of a dollar.

The blade heights should vary from about 4 per cent. to 14 per cent. of the mean diameter, in which case this clearance only represents a very small percentage of loss. Various metals have been used for the blading; generally a form of cheap brass has been employed for both blade and packing piece. Steel blades have been used in this country, while the best metal yet found for working with high temperature steam is an alloy containing 80 per cent. of copper and 20 per cent. of nickel, this being specially strong and durable, though almost pure copper gives excellent results.

The usual form of caulking piece adopted is shown by the shaded portion in Fig. 8, which outlines the action of steam in the blades. The distorting effect of caulking on large cylinders is distinct unless they are well designed, and the assembling process may appear slower than it really is.

The author is convinced that this form of caulking-piece must largely disappear in favor of a machine-divided strip, such as some firms are now using. This form of blading not only ensures perfect accuracy but is a remarkably cheap one, saving several processes over the old method. The slotted strip (see Fig. 9) is associated with a shallow shroud ring into which the blades are fitted, being thus held at the tips as well, the whole arrangement forming a very strong and durable method of attachment.

As to blade-stripping, nearly every case may be attributed to carelessness in design, manufacture and operation. The unequal distortion of cylinders by heat—a matter of great importance in marine turbine work where flexible shaft couplings are impossible—accounts for most stripping; the passage of grit or water is not so formidable as might be imagined. Any whipping of the turbine spindle will destroy the tip clearances (and the blades too), but careful design should never permit this; defective or unsuitable blade material is another preventable cause, and there is also the possibility of bad workmanship. In a properly designed and well-made turbine the chance of blade-stripping is very minute.

The bearing pressure permissible in marine turbines is about 80 to 90 lbs. per sq. in.; the circumferential speed of the shaft, however, must be kept down to about 25 or 30 ft. per second, if such a pressure is used; in electrical work 50 lbs. and 50 ft. per second is more usual. Under these conditions and with ample oil supply the necessity for adjustment will be very rare. Rigid bearings, lined with white metal are used.

The centrifugal stresses are very low in marine turbine spindles; in fact about 200 ft. per second is practically the highest vane speed obtainable, in which case the stress will not exceed 4,000 lbs. per sq. in., but usually it is very much lower.

The propeller thrust is balanced by the action of the steam in a very satisfactory manner, but this calculation involves knowledge of effective thrust along the shaft in order to accurately proportion the annular area on which the steam pressure is to act. The result is that the spindle is in compression and the cylinder in tension when the turbine is working; a margin is always allowed so that the propeller thrust exceeds the steam thrust.

Owing to the unfortunate propensity of iron and steel to expand when hot, care must be taken to allow the resultant movements to take place freely; the after end of the cylinder is secured to the ship, and through it is transmitted the propeller thrust, while the other end slides forward. The warming up of large turbine cylinders requires considerable care.

Governing is largely unnecessary in marine work, as the fly-wheel effect of the motor tends to prevent any sudden fluctuation in speed, even if the greater immersion of the propellers does not prevent racing.

The radiation from the low-lying turbine cylinders is sometimes very unpleasant, and in warships, with their low, armored decks, ample ventilation facilities are necessary. No method exists of indicating the power, such as is possible in piston engine work, but the determination of brake horsepower can easily be made with great accuracy; in electrical work a water brake is simplest, while the electrical torsion meter invented by Messrs. Denny and Johnson, allows an easy method of arriving at the B. H. P. in marine turbines, and, unlike the water brake, can be applied when the turbine is at work.

Regarding the vexed question of efficiency, it is obvious that no such large loss of power due to engine friction exists with turbines as it does in reciprocating engines. Then again, the small propellers used are driven very hard at full speed, and at lower speeds their efficiency increases; it falls off in piston-engine work due to excessive size.

Where the effective horsepower is unobtainable from tank trials, it is usual to take a similar propulsive coefficient to that found in corresponding classes of piston-engine practice.

The turbine efficiency remains constant over a wide range of size, while the propeller efficiency increases distinctly with lower thrust pressures and larger dimensions for the work to be done. The weight of the turbines, however, varies approximately as the inverse square of the revolutions.

CONCLUSION.

The author must beg of much leniency on the part of members for the length of this paper.

The application of a new form of motor is not to be undertaken lightly, and the author has in consequence tried to embody as many facts as possible. He is well aware that innumerable subjects of interest in the adoption of such a system have been passed over or insufficiently touched upon, but the whole subject is new to the transactions of this Society, and while portions of the paper may be of less interest than others, it is possible that it may be useful to have them on record in this country. It is hoped that the photographs and diagrams will, to some extent, explain what has not been touched on in the text.

If there seems any tendency to exalt the turbine unduly, it must be dismissed from consideration; the reciprocating engine is by no means obsolete. It has played a most useful part in the world's engineering, and if it should happen that it must go before the rapid advance of the rotary engine, and for many classes of vessel it has already supplanted—it may be remembered that sails had to make way for pistons, and that while the American cup is still to be won it is unlikely that they will disappear entirely.

THE CONFLICT OF ENGINEERS OVER PLANS FOR THE PANAMA CANAL.

There has recently been published for limited private circulation, a series of three papers on the Panama Canal problem, prepared by Mr. Wm. Ham. Hall, M. Am. Soc. C. E., of San Francisco, Mr. Hall is one of the best known engineers on the Pacific Coast. For a number of years he was State Engineer of California during the administration of Gov. Geo. C. Perkins who is now U. S. Senator from California.

Mr. Hall's papers are in the form of letters to Senator Perkins discussing the relative merits of the several different plans for the canal and explaining some of the reasons for the conflict of opinion among engineers.

These papers were prepared several months ago before the Advisory Board of Engineers began its work. Had this Board rendered a unanimous report, recommending a type of canal on which all parties could agree, there would have been no need for the publication of Mr. Hall's discussion. Under the present circumstances, however, with a conflict of opinion in the Advisory Board, the whole question as to the best plan for the canal becomes one on which engineers generally will desire information. We have deemed it worth while, therefore, to publish a large part of Mr. Hall's discussion.

We may preface it by saying that, while Mr. Hall bases his discussion and criticism entirely on the official published reports of the various Panama Commissions, he has an intimate personal knowledge of conditions on the Panama isthmus, acquired in the course of work for private clients.

In order to make the discussion more intelligible to the reader, we have accompanied Mr. Hall's paper with a map of the Panama Isthmus showing the canal with a summit level of 90 ft., as recommended by the Isthmian Canal Commission of 1901, the summit level being created by a dam across the Chagres river at Bohio.

Mr. Hall's first paper is a review of the plans for a Panama canal as prepared by the six successive official organizations of engineers which have up to April last had to do with the enterprise. We may note here that since that date two others—the present Commission and the Advisory Board have been added to the list; but the results of their work are of course not considered by Mr. Hall.

In this paper Mr. Hall confines himself chiefly to summarizing the past engineering history of the enterprise and making clear the sharp conflicts of opinion between the successive engineering commissions. The other papers, which will follow in later issues, critically discuss the several plans.

PART I.

A Statement of the Panama Canal Engineering Conflicts.

The International Congress composed of 135 delegates from the several European maritime countries and from our United States, but most of whom were from France, assembled in Paris in May, 1879, to consider the American Isthmian Canal enterprise. Within a session of two weeks this Congress declared for the Panama route and in favor of a sea-level canal on that route. At that time the data practically bearing upon the construction problem was meager, conditions were but little understood, and such an assemblage could not, especially under such circumstances, be expected to thoroughly consider the technical problems involved in the canal planning.

THE OLD PANAMA CANAL CO.

Immediately following the adjournment of the Congress, M. Ferdinand de Lesseps, buoyed by the prestige due to his Suez Canal accomplishment, promoted formation of the Compagnie Universelle du Canal Interoceanique, for building the Panama Canal, and was made its President. His company, since popularly called the Old Panama Canal Co., adopted without further investigation the sea-level plan.

THE SEA-LEVEL PROJECT OF M. DE LESSEPS.—M. de Lesseps' famous program, drawn up as a guide for the investigation and report by the International Board of Engineers which he called together, did not include inquiry into any lock-level project. The Board had no authority to consider anything except his sea-level proposal. And at a meeting of the American Society of Civil Engineers held in January, 1880, at which M. de Lesseps was present as a guest, he said that had that Board of Engineers reported in favor of a lock-level project, "I would have put on my hat and walked out," leaving realization of the work to some one else. M. de Lesseps was a promoter and not at all an engineer. The conception of joining the Pacific with the Atlantic was a catchy one which could be made to do efficient duty in the course of the financing which the great promoter had in hand. He did not want it said that there were any "gates to be opened and closed," or any "stairs to be climbed" in the course of his grand waterway.

The surveys and examinations which occupied the old company for the first two years were directed to the definite locating of the canal and auxiliary works, and planning and estimating cost thereof on the sea-level project, and not with the view of determining whether such a canal for the Panama route was to be preferred to one with some higher levels and locks to reach them.

THE SEA-LEVEL PLAN ABANDONED.—Work was carried forward on this sea-level project until 1887, when that plan was set aside for one with locks and high levels through the continental divide where work on the deep excavation known as the Culebra cut had developed sliding ground that proved a terror to the constructors. Moreover, owing to difficult foundation conditions disclosed by closer examination, the idea of the great regulating and storage dam at Gamboa had been abandoned by M. de Lesseps and his engineers, so that the control of Chagres River floods and canal water supply remained unprovided for in their plans. The setting aside of the sea-level idea was declared by M. de Lesseps and his confreres to be but temporary, but it was plain that it never could be revived by them, and the engineering literature and public opinion of that time, other than French, and more especially American, were overwhelmingly opposed to the sea-level plan and in favor of a canal with higher levels.

The de Lesseps Company continued work nearly two years longer and was then adjudged bankrupt, in February, 1889. A liquidator appointed by a French Court to take charge of the affairs of the company, gradually closed down the construction work until it ceased in May, of the same year. He appointed a "Commission d'etudes," composed of eleven members, French and foreign, who reported in May, 1890, that the value of the work to that time accomplished was approximately $87,000,000, that the work of construction could be completed by a plan with high levels and locks which it recommended, within eight years and at a cost of $112,500,000, or $174,600,000 including administration and financing expenses. According to the report of the liquidator, submitted to the court in November, 1895, the old company and the liquidator had raised in money $246,706,431.68, by the sale of stock and bonds, whose face value was $435,559,332.80. There had been excavated about 72,000,000 cu. yds. of material; machinery and other construction plant had cost about $20,000,000, and nearly all of the shares of the Panama Railroad Company had been purchased at a cost of about $18,094,000.

THE NEW PANAMA CANAL COMPANY.

The New Panama Canal Company, organized in October, 1894, appointed a Technical Committee, composed of 14 European and American engineers to thoroughly investigate the whole subject and report a plan for the canal. The report, dated in November, 1898, after four years of investigation, which is vouched for on high American authority as having been most thorough, rejected the sea-level idea, and recommended a plan having a summit level of 97.5 ft., and a medial lake level of 66 ft. elevation, to be formed in the Chagres Valley by a dam to be built at Bohio. The terminal divisions, as far as Miraflores on the Pacific and Bohio on the Atlantic, were to be open sea-level cuts.

Under its charter the new company was required to appoint an Engineering Commission of five members to report on the project when its preliminary capital should be one-half expended. The report of the Technical Committee was referred to the Statutory Commission thus formed. This body in turn reported in February, 1899, confirming the plan of the Technical Committee. The Gamboa site for a flood-regulating and water-supplying reservoir was condemned because of the alleged bad foundation for a dam to be built to the height necessary to accomplish the desired purposes, and a site at Alhajuela, 9 to 10 miles further up the Chagres Valley, was selected for such a work, where the dam foundation and abutments would be exceptionally good and the reservoir space above would be all-sufficient, when taken in connection with the Bohio lake, for the flood regulation and water supply purposes. The Bohio dam site was admitted to be difficult for any dam to be carried down to bed-rock, but it was considered safe for an earthwork dam to be built by usual methods on a thick clay bed found in the gorge by borings at and near to the dam site, and to hold water to the maximum depth contemplated in the plan. The regulated water escape from Alhajuela reservoir was to be received into Bohio lake by the river. The tributary waters below Alhajuela to Bohio were also to be received into the lake. A flood relief channel was planned on each side of the valley, from the lake to the sea. These channels were to carry away the overflow waters from the lake, and also to intercept and carry the tributary waters of the lower valley. The lake's surface was expected to fluctuate in the absorbing and passing of floods.

The minimum canal bottom width was placed at the least water depth, at 29.5 ft. There were to be on the Atlantic slope two double locks in flight, having maximum lifts of 33 ft. each, to connect the sea-level canal to the full lake level at Bohio, and two more locks to connect the lake level with the summit canal, at a point about a mile south of Obispo. On the Pacific slope there was to be a tide lock at Miraflores at the head of the sea-level section through the Pedro Miguel low-lands, and four other locks at points above to reach the summit level, making nine locks in all. All the locks were to be 738 ft. clear length, 82 ft. clear width and 32 ft. 10 ins. clear depth—thus providing for the future canal excavation to nearly a similar depth. The summit level canal was to be supplied with water by a feeder canal extended to it from the Chagres River below the Alhajuela reservoir dam. The cost of completing the whole work by this plan was estimated at $101,850,000, not including administration and financing expenses.

A LOW LOCK-LEVEL PROJECT PREFERRED.—The Technical Committee formulated and the Statutory Commission reviewed also a second plan, which was substantially the same as the first, omitting the summit-level—that is to say, the cut through the summit ridge was to be made to a depth which would carry the 90 ft. Bohio lake level through as a summit canal level. This latter plan dispensed, of course, with the two upper double locks, on the Atlantic slope, and with two locks on the Pacific slope, leaving five, including the Miraflores tide lock, in all. It also dispensed with the feeder canal, which by the first plan was to supply water to the 97.5-ft. summit-level. The estimated cost by this plan was $105,500,000.

From the engineering standpoint both the Technical Committee and the Statutory Commission preferred the second or lower level, of these two plans, but, notwithstanding the estimated costs by the two differed but little, both these bodies of engineers feared that the great time which might be necessary to execute the work by the second plan, involving the much deeper cutting through the continental divide, would so much run up the expense of administration, the cost of financing and the loss by accumulation of interest, that for their commercial company the first or high level plan was the safest, and, so, was to be preferred.

GENERAL HENRY L. ABBOT'S WORK.—In his recently published book on the "Problems of the Panama Canal" General Henry L. Abbot, who was a member both of the Technical Committee and the Statutory Commission of the New Company, and also one of its consulting engineers, describes the modified plan as the main engineering project favored by himself and engineer associates, and he practically recommends it as the one which, in longitudinal profile, is best suited for our government work.

THE ISTHMIAN CANAL COMMISSION.

Under the Act of Congress of April 3d, 1899, the President of the United States appointed on June 10th, 1899, an Engineer Commission of nine members "to determine the most feasible and practicable route" for a canal across the American isthmus.

In its first report this Isthmian Canal Commission embodied description of a plan for a canal by the Panama route on which it based its estimate of cost, presumably for purposes of comparison with its estimated cost of a work by the Nicaragua route. In doing so it definitely rejected the sea-level cut through the continental divide, and reported in favor of a canal with a higher level reached by locks, as follows:

As in all former plannings the sea-level was to be carried from the Pacific to Miraflores and from the Atlantic to Bohio. At the latter place a dam was to be constructed to make a lake whose full water surface would be 90 ft., and low water plane 82 ft., above mean sea level. This was to be the summit level, and the continental divide was to be cut thence, so as to carry in the canal 35 ft. in depth below the above mentioned (lake) low-water plane, and with a bottom width of 150 ft.

Two double locks in flight, each with a maximum lift of 45 ft., were to connect the Atlantic sea-level canal with the lake level at Bohio. A double tidal lock at Miraflores, with a maximum lift of 38 ft., and two double locks in flight, each with a maximum lift of 31 ft., at Pedro Miguel, were to connect low tide level with the summit level on the Pacific side. The lock chambers were to be 740 ft. in length and 84 ft. in width, clear dimensions. Guard gates were to be introduced at the opening of the summit cut from the head of the Bohio lake, so that the cut might be emptied if necessary, without drawing down the lake waters.

The plan contemplated receiving all upper as well as middle Chagres and tributary waters, directly into the Bohio lake without any controlling reservoir either at Gamboa or Alhajuela, and to this end the Chagres valley towards the head of that part of the lake used for the canal purpose, was to be enlarged in cross section so as to reduce flood flow velocities below rates which might

embarrass navigation. Thus, the Bohio lake was to be the sole regulator of Chagres floods, and with this view the plan provided that its surface might be allowed to fluctuate the eight feet from elevation 82 to elevation 90 above indicated, while a great spill-way over bedrock at Gigante would waste water as soon as the surface rose above the 85-ft. plane.

The Gigante spill-way would deliver the floods into a tributary leading into Chagres Valley several miles below Bohio dam site. Thence the waters would be kept out of the canal by means of an embankment and conducted by an immense cutting to a point on the lower Chagres beyond where they could get back into the navigation canal. This disposed also of lower Chagres tributaries from the west. The northeast side tributaries were to be intercepted by a canal and carried away, as in the French plans, which had, in this part, been largely carried out.

THE PANAMA CANAL COMMISSION.

On June 26, 1902, the President approved the Act of Congress providing for the construction of a Panama Canal, and on Feb. 29, 1904, the President appointed a Commission of 7 members to have charge of the canal construction.

The originally appointed members did not as a commission make any general report of their plannings. It is known, however, that the Commission did not adopt the plan estimated upon and provisionally recommended by its predecessor, the Isthmian Canal Commission, and on the basis of which, presumably, the Panama Canal Construction Act had been passed. It set about studying anew the problem of character to be given the canal, and to this end, as well as to advise upon engineering work in progress, it appointed three of its members as an Engineering Committee.

THE COMMITTEE'S PROJECT—SEA-LEVEL PLAN.—This committee made a report under date of Feb. 14, 1905, which contained the following recommendations: "That the summit level of the canal should not exceed 60 ft. above mean sea level." "That in the event of the Commission approving the foregoing recommendation, the Chagres river be retained by a dam located at Gamboa, and built to a crest height of 200 ft."

After further discussing the problem on the basis of data acquired by the examination and work carried on under the Chief Engineer's direction, and explaining that waters might be wasted from the Gamboa lake either by way of sluices into the canal or through certain tunnels to be driven several miles in length through the mountain ridges to the Pacific or the Atlantic watershed, the Engineering Committee made a closing recommendation as follows:

That this Committee approve and recommend for adoption by the Commission a plan for a sea-level canal, with a bottom width of 150 ft. and a minimum depth of water of 35 ft., and with twin tidal locks at Miraflores, whose usable dimensions shall be 1,000 ft. long and 100 ft. wide, at a total estimated cost of $230,500,000. Such estimate includes an allowance for administration, engineering, sanitation and contingencies, amounting to $38,450,000, but without allowance for interest during construction, expense of zone government and collateral costs, and water supply, sewers and paving of Panama and Colon, which last items are to be repaid by the inhabitants of those cities.

A SUMMARY OF THE SEVERAL PROJECTS.

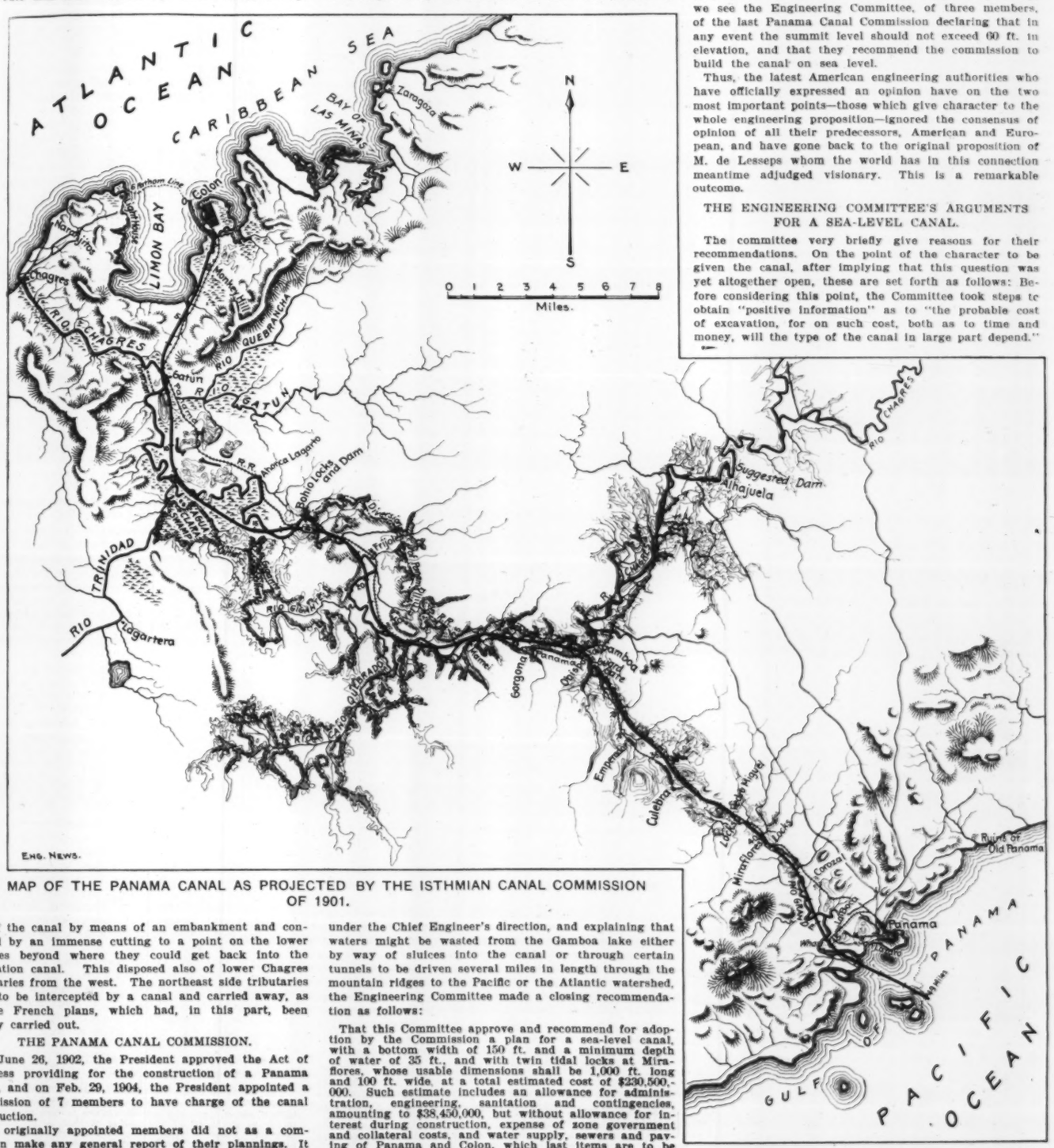
This completes an outline of the notable official recommendations as to the type of the Panama Canal from the time of the Paris Congress in 1879 to the retirement of the members first appointed on the American Panama Canal Commission at the end of April, 1905.

From it we see: The International Congress and the de Lesseps Company declare for a sea-level canal. We see this company, after nearly eight years of work, set aside that idea for a plan with a high summit level and locks. We see the New Panama Canal Company's Technical Committee of 14 engineers, and its Statutory Commission of 5 members both roundly condemn the sea-level canal idea. We then see the American Isthmian Canal Commission of 9 members also condemn the sea-level canal idea and advance a plan involving one high level at 82 to 90 ft. of water elevation. And, finally, we see the Engineering Committee, of three members, of the last Panama Canal Commission declaring that in any event the summit level should not exceed 60 ft. in elevation, and that they recommend the commission to build the canal on sea level.

Thus, the latest American engineering authorities who have officially expressed an opinion have on the two most important points—those which give character to the whole engineering proposition—ignored the consensus of opinion of all their predecessors, American and European, and have gone back to the original proposition of M. de Lesseps whom the world has in this connection meantime adjudged visionary. This is a remarkable outcome.

THE ENGINEERING COMMITTEE'S ARGUMENTS FOR A SEA-LEVEL CANAL.

The committee very briefly give reasons for their recommendations. On the point of the character to be given the canal, after implying that this question was yet altogether open, these are set forth as follows: Before considering this point, the Committee took steps to obtain "positive information" as to "the probable cost of excavation, for on such cost, both as to time and money, will the type of the canal in large part depend."



MAP OF THE PANAMA CANAL AS PROJECTED BY THE ISTHMIAN CANAL COMMISSION OF 1901.

The Committee then tell of the work of two American steam shovels for a couple of months, and say:

As the result of the experience thus far gained in the actual rock and clay excavation at Culebra, the average monthly cost per cubic yard has fallen below 50 cts. The Chief Engineer, therefore, is confident that the cost of all the excavation in the summit cut will not exceed 50 cts. per cu. yd., and this Committee concurs in that opinion.

The Committee then recalls that this work was esti-

mated at an average of 80 cts. per cu. yd. by the Isthmian Canal Commission. Consequently upon their lower unit rate for excavating, the Committee say that on the quantities estimated by the former Commission, a saving of about $15,000,000 might be expected; and as a conclusion they write:

This large saving in cost makes a fundamental reconsideration of canal plans by this Commission essential. It is obvious that this actual reduced cost of excavation justifies a reduction in the elevation of the summit level of the canal by a correspondingly greater volume of excavation.

SEA LEVEL PLAN RECOMMENDED.—Having thus brought forward the economy in excavation to be expected from the more modern American machinery, and having shown that the upper Chagres floods can be kept out of the canal by a Gamboa reservoir, and mountain ridge tunnels thence to the oceans, the Committee says:

The practicability of certainly and satisfactorily controlling the floods of the Chagres by so simple and economical a method as the Gamboa Lake and its outflow channels and the reduced cost of excavation as actually demonstrated by the work of the Commission in the Culebra Cut, make the construction of a sea-level canal at a reasonable cost far more available than has heretofore appeared possible. These recent developments in the conditions attending the construction of the canal are so important as to be almost controlling in character. The remaining element is that of the time required to make the great summit excavation. . . . . With the rate of progress which now appears reasonable to anticipate this Committee believes that a sea-level canal with a tidal lock 1,000 ft. long and 100 ft. usable width, at Miraflores, can be completed within 10 to 12 years from this time, the bottom width of the canal being 150 ft. and the minimum depth of water 35 ft. These considerations have induced the Committee to express to the Commission its unanimous judgment that with the contemplated system of working, and with the rate of development which appears to be justified by the work now being performed at Culebra, a sea-level canal, free from the restriction of locks, should be adopted. This Committee believes that such a canal, with terminal harbors, can be constructed for a sum not exceeding $230,500,000.

THE ENGINEERING COMMITTEE'S ESTIMATES.—The comparative estimates of the Engineering Committee "including the breakwater, direct approach channel and interior harbor at Colon," are as follows:

Summit level at 60 ft. elevation	$178,013,406
Summit level at 30 ft. elevation	194,213,406
Sea level	230,475,725

These totals include a margin of 20% for contingencies, administration, sanitation and engineering. The estimates in all cases cover the committee's Gamboa plan for flood regulation, but it is not said whether the long tunnel idea is incorporated or not. Like the former plannings, this sea-level one contemplates handling the floods which come into the lower Chagres (below Bohio), and which would otherwise enter the navigation canal cutting, by means of diversion canals. What is proposed for tributary floods reception and passage in the middle Chagres valley, from Gamboa to Bohio, is not clear from the Committee's report. Neither does it appear what dam, if any, the Committee or the Chief Engineer has planned in the 30 or the 60-ft. summit level projects estimated upon.

THE BOHIO DAM SITE DEPRECATED.—As to the Bohio dam site the Committee say: that their borings show it to be 158 ft. down to bed-rock at the Isthmian Canal Commission's section, or 30 ft. deeper than the Commission counted upon, and but little less depth has been found at any site there; that

these results indicate greatly increased difficulties in the construction of any dam in the vicinity of Bohio. The borings, like others previously made in this locality, have disclosed coarse, gravelly material, freely water-bearing down to bed-rock at many points, as well as occasional fragments of timber. This clearly indicates the necessity of cutting off subsurface flow along the deepest bed-rocks, in case a dam should be built at this location. These conditions are formidable because they are found at such great depths.

This wording ignores the existence of any bed of practically impervious material overlying the pervious deep gravels, and suitable for a foundation for an earthwork dam, or denies the existence of such a bed, or condemns the idea of putting a dam on it under the circumstances and without cutting off percolation through the deeply underlying gravels. It is a deprecation, practically a condemnation, of the Bohio dam site, and, hence, of Bohio lake as a part of the desired waterway and as a Chagres regulator, and hence, is an argument in favor of the Gamboa regulation site and of abandonment of all lock-level plans in favor of the sea-level idea.

A SUMMARY OF THE SEVERAL ENGINEERING CONFLICTS.

Glancing over this record, we see four sets of high engineering authorities widely at variance on the most vital points of this great problem. All of them, full 30 in number, except the last Engineering Committee, of three, have set aside or condemned the sea-level idea, either as—not the best plan, too expensive in time or in money, or both, impracticable, dangerous for adoption, or chimerical. But the Engineering Committee say that it is eminently practicable, is the best plan, and is not too expensive either in time or in money, and should be adopted.

CHAGRES REGULATION PLANS.—The projects for regulation of the Chagres River have been as varied, almost, as the topographic features of the country will admit of. First, the Gamboa reservoir, all-sufficient in capacity and with an alleged good dam foundation. Again: condemnation of Gamboa dam site, selection of Alhajuela reservoir with alleged most excellent dam site and sufficient capacity, projection of Bohio lake as part of waterway, and combination of Bohio lake with Alhajuela reservoir as Chagres regulators. Still again, ignoring of all preceding, adoption of a higher and bigger Bohio lake as part of waterway, as water conserver and sole Chagres regulator. And, finally: practical condemnation of Bohio dam site, and recommendation of Gamboa reservoir as the sole regulator and as having a good dam site. Here are three distinct projects in succession, and then a return to the first.

BOHIO DAM PLANS.—But this was not all. Of those who adopted the idea of making a lake in the middle Chagres valley by a dam at Bohio, no two authorities chose exactly the same dam site, and no two planned and estimated upon the same kind of a dam. The New Company's International Commissions proposed an earthwork dam without any masonry, concrete, clay or other core, and of ordinary cross-section. They planned it to rest upon a thick bed of firm clay alleged to have been found in the alluvial filling in the canyon section and notwithstanding that borings revealed the existence of permeable water-carrying gravels beneath it. But they provided that the up-stream slope of the dam was to be covered with a heavy facing of stone laid in cement mortar, and there was to be a concrete wall, around the foot of this facing, extending down into the clay some feet but not nearly through it. The Isthmian Canal Commission first chose a masonry type, but later planned, estimated and recommended an earthwork dam with a heavy masonry core to be carried down, by a pneumatic process of construction through all the clays and gravels to bed-rock, whose maximum depth was found to be 128 ft. below the tide-level.

With a saving clause presently to be noted, this difference of plan presents a conflict of professional opinion as sharp and vital as it well can be. The New Company's Commissions considered it entirely safe to build an earth work dam of ordinary type, without any special core, on the "firm sandy clay" bed. They did not think it necessary to cut off percolations through the deeply underlying sands or gravels, as a measure of protection to the clay foundation and dam. The Isthmian Canal Commission, apparently did not consider it safe to build on the alluvial formation, without putting an impervious diaphragm through all the alluvial matter down to bed-rock, and so they provided a thin partition of masonry to rest on bed-rock. But this was not their reason in chief for this feature of their plan. The New Company's Commissions, apparently, not only believed that the deep bed of firm sandy clay would be a sufficient and safe foundation for their proposed dam, but that the loss of water from the lake above the dam, through the permeable sands and gravels deeply underlying the foundation bedding, would not be enough to endanger sufficiency of water for canal purposes. The Isthmian Canal Commission thought that the water supply would be endangered through loss by seepage if the percolation through the underlying permeable strata were not cut off. But, further than this, the Commission, apparently mistrusting an earthwork dam, in itself, for the duty above ground, extended the masonry diaphragm, as a core, up through the earthwork superstructure to its top.

Finally, the New Company's International Engineers also seem to have, in some measure, mistrusted an earthwork dam, but, in sharp contrast as to means for bettering it, they provided for covering theirs on the water side with a thick rock paving laid in cement mortar.

In all this connection we must remember, however, two important points, and this is the saving clause: (1) The French and International authorities contemplated holding the water to a depth of only 66 ft.; while the American authorities were planning to hold it to 90 ft. in depth. (2) The first set of engineers provided, in their projected Alhajuela reservoir (which, it was alleged would not waste water at all), an additional and upper basin for storage of supply for canal purposes, so that if their Bohio reservoir did under its 66-ft. head lose more water by seepage than they believed it would, they yet had ample provision for sufficient supply in the independent reservoir at Alhajuela; while the American commission contemplated no other storage space than the Bohio lake itself wherein to receive and conserve water for all purposes.

Manifestly there would be more likelihood of material loss by seepage under a 90-ft. than a 66-ft. head of pressure. The provision of independent and all-sufficient storage space at the higher reservoir site might be expected to replenish the 66-ft. reservoir against the lesser amount of loss, while the 90-ft. reservoir would not have any such safeguard against results from its probable greater seepage waste. Hence, the apparent greater necessity for some measure designed to stop percolation through the deep strata under the American than under the French project for the Bohio lake. But even so, these projects point a lesson which I shall later draw.

MR. GEORGE S. MORISON'S BOHIO PLAN.—The New Company's Commission appear to have been unanimous in the adoption of their type of dam, which the Isthmian Canal Commission was not. At least one of its members, Mr. Geo. S. Morison, Past-President Am. Soc. C. E., a civil engineer of great experience and high standing, though he signed the Commission's report, did not approve of its plan for a dam. Mr. Morison submitted his plan to the profession in a paper read before the American Society of Civil Engineers in March, 1902. He agreed with the New Company's Commissions in accepting the Bohio dam site as safe for an earth dam to rest upon the clay and to hold water not only to the 66-ft., but to the 90-ft. plane, without danger of excessive loss by seepage. But he planned and recommended a different type of dam—a far heavier and thicker structure, with a rock-fill embankment to support each footing and a sheet-pile and puddle tongue to unite it with the clay bed on which for a space it was to rest. Here was another conception of the adaptability of the Bohio site.

But finally comes the Engineering Committee of the last Panama Canal Commission, and, in effect, say that the site is not adapted for the purpose of a storage dam at all.

THE TERMINAL DIVISION.

There is, however, one point in planning upon which all the official engineers seem to have agreed. They have all contemplated cutting a sea-level channel from the Bay of Panama, as far as Miraflores on the Pacific side, and from the Bay of Limon, at least as far as Bohio, on the Atlantic. True, there has been talk of a dam at Gatun, a lower point on the Atlantic side, but no official proposal has incorporated that feature.

And, so, we find that all of the official engineers have planned to make the canal at sea-level for at least 19.9 to 22.9 of the 46 to 49 miles of its total length. This has resulted in (1) the vast volume of dredging, or below-water excavation counted upon in all the estimates, (2) the provision for great intercepting canals and embankments flanking the valley to keep tributary flood waters out of the navigation channel, (3) the provision of immense cuts and embankments to divert and keep Chagres flood waters out of the navigation channel, and (4) the compulsory retention of the lower Chagres and Panama swamp areas which are the greatest breeders of pestilential influences on the Isthmus.

TERMINAL LAKES PROPOSALS.—In 1879 Mr. C. D. Ward, M. Am. Soc. C. E., proposed the making of two navigable lakes in the Panama Canal line, by dams at Gatun, on the Atlantic, and La Boca, on the Pacific side, respectively. These lakes would reduce the sea-level parts of the canal by about 9 miles on the Atlantic and nearly 4 miles on the Pacific end, adding an equal length of lake navigation. This was an American conception of proper treatment of the Panama canal problem—to make lake navigation by dams as far as practicble, and it found its strongest supporters among the American hydraulic engineers of the time.

In discussing a paper on "Inter-Oceanic Canal Projects" by A. G. Menocal, M. Am. Soc. C. E., in 1880, the late Ashbel Welsh, Past-President Am. Soc. C. E., "a thorough and noted canal engineer in his day," said:

The first thought of an American engineer on looking at M. de Lesseps' raised map, is to convert the valley of the lower Chagres into an artificial lake some twenty miles long, by a dam across the valley at or near the point where the proposed canal strikes it a few miles from Colon, such as was advocated by Mr. C. D. Ward.

This site was at Gatun, nine miles below Bohio. All such ideas were ignored by M. de Lesseps' company, bent on realization of the sea-level cut. Later they repented. Still later Bohio was chosen by the New Panama Canal Company's Engineering Commissions, as the site for a dam to make a 66-ft. water-plane lake. Our Isthmian Canal Commission confirmed this selection, but for a still higher level (90-ft.) lake; and reported that "no location suitable for a dam site exists on the Chagres River below Bohio."

In May, 1904, Mr. C. D. Ward again brought forward his idea of the Gatun and La Boca dams to canalize, practically, the low valleys of the terminal divisions of the canal route. In a paper then read before the Am. Soc. C. E. he advocated a dam at each of these points to make lakes with water levels as high above sea as could be reached by one lock each.

Following this, in February, 1905, the Engineering Committee reported as follows:

The surveys and examinations which have been made in regard to a possible dam across the Chagres river at Gatun show that such a structure is not feasible. The width of the floor of the valley at that point is 5,000 ft., and two borings made at what appears to be the most favorable section, penetrated to a depth of 172 ft. and 139.2 ft. below sea level, respectively, without finding bed-rock. Other examinations and borings have also been made at other sections of the Chagres valley where a dam site seemed possible, between Gatun and Bohio, but with equally unfavorable results. It is clear, therefore, that it is not possible to construct a dam across the Chagres at any point lower down in its course than at Bohio.

It may seem that these adverse opinions as to practicable dam sites below Bohio should put an end to proposals for canalizing the lower Chagres River valley, by the creation of a navigable lake therein, but close read-

ing of them and consideration of known facts does not justify such conclusion.

MR. LINDON W. BATES' PROPOSALS.—Finally, in the outlining of the later projects which have been made for the Panama Canal, there remains to be noticed those of Mr. Lindon W. Bates, issued in printed form and illustrated by maps, etc., in May, 1905.

The first of these adopts the terminal lakes idea of Mr. Wood, except that Mr. Bates chooses a site for his Lower Chagres Valley lake dam at a point on the river several miles below Gatun and below where the canal route is within the valley. Supplementing this dam, to form the lake and regulate its waters, Mr. Bates proposes an embankment and barrage, or masonry dam with gates in it, on the low divide through which the canal route enters Chagres valley from Limon bay. At this locality would be a lock, of course, in the line of the canal. The Pacific terminal lake, occupying the swamp valley of the Rio Grande, would be formed by a dam, as proposed by Mr. Ward at La Boca, and would be there supplemented by a regulating barrage as proposed for the Chagres lake at Boca Mindi; there being also a lock, of course. This Bates project adopts 20 to 30 or less feet as the water plane elevation of the lakes, and this elevation is to be carried through by canal from lake to lake.

To regulate the upper Chagres River and supply lockage water throughout the dry season, the plan contemplates a dam and reservoir at the Alhajuela site. The tributary waters entering lower Chagres valley are to be received into the lake. The tributary waters through the middle Chagres division are to be received into the canal. On this point, at least, Mr. Bates' project is not altogether clear. The canal is to have an expanding section from Obispo, each way to the two lakes, and be of large enough dimensions to carry the waters brought to it, without generation of damaging or inconvenient currents. A part of the flood waters are expected to debouche through the Panama arm of the water-way. This Bates plan is a low-lock-level proposition combined with the Alhajuela regulating reservoir feature, and with a short sea-level approach to the terminal lakes, at each end.

As an alternative plan Mr. Bates proposes to introduce and combine with his low terminal lakes project, a summit level at elevation 50 to 52, or somewhat more, feet, made by a dam at Bohio forming a lake whose water surface level would be carried through by a canal cutting to Miraflores. The additional steps up and down would be made at Bohio and Miraflores with one lock each. The upper Chagres reservoir at Alhajuela would be retained. The Gigante spill-way would be utilized for passage of water from the upper to the lower level on the Atlantic side, and another bed-rock spill-way would be constructed near Miraflores for like purpose on the Pacific side. The waterway in this case would consist of a short sea-level approach at each end, two low terminal lakes, a Bohio summit lake and a summit canal cutting on Bohio lake level.

This is a return, as far as it seems may be practicable, to the general proposal made about the beginning of this discussion, 25 to 30 years ago, by some of the leading hydraulic (canal) engineers of the time. The idea being to canalize as much of the natural waterways or low grounds as possible by the building of dams, rather than the cutting of channels through them. Whether the conditions admit of realization of the low terminal lakes, remains to be known. Mr. Bates has put the idea into more definite and complete form than, so far as the writer knows, it had heretofore appeared in print.

THE TREATMENT OF WATER WITH COPPER SULPHATE AT DENVER, COLO.

By Geo. T. Prince.*

During the past year the Denver Union Water Co. treated two bodies of water with copper sulphate in order to eliminate algae: (1) A small lake at City Park and (2) the company's Marston Lake reservoir. The lake in the park was treated for experimental purposes, in order to determine the effect of copper sulphate upon the algae with which the water was then badly affected. At the time of the test the surface of the water was nearly covered with a green scum. At the same time a disagreeable fresh corn odor from the water was quite annoying. It was thought if the copper would eliminate the algae from this water it certainly could be used with good prospects of success in freeing our reservoirs from the unpleasant effects of algae, should occasion require, and this proved to be necessary within two months thereafter. The treatment of the Marston Lake reservoir is of special interest because of the large quantity of water involved.

Tables I. and II. give the results of examinations of the water before and after treatment. The following comments relate to Marston Lake.

Before the treatment with copper sulphate the lake had a bluish-green appearance, but no surface scum was observed. The copper had an immediate effect on most of the organisms. Samples were taken while the water was being treated and every 24 hours afterwards for five days, with the favorable results shown in Table II.

The sample taken 24 hours after treatment showed no Anabaena whatever. Forty-eight hours after treatment the bacteria had multiplied very rapidly on the food furnished by the dead organisms. On the fifth day the bacteriological count had increased to 107,500 per c. c., and practically no organisms were to be found. The lake had the characteristic steel-blue appearance.

Another sample was taken nine days after treatment and no organisms were present. An examination of the water coming into the lake showed no trace of Anabaena. The only species present were a few diatoms.

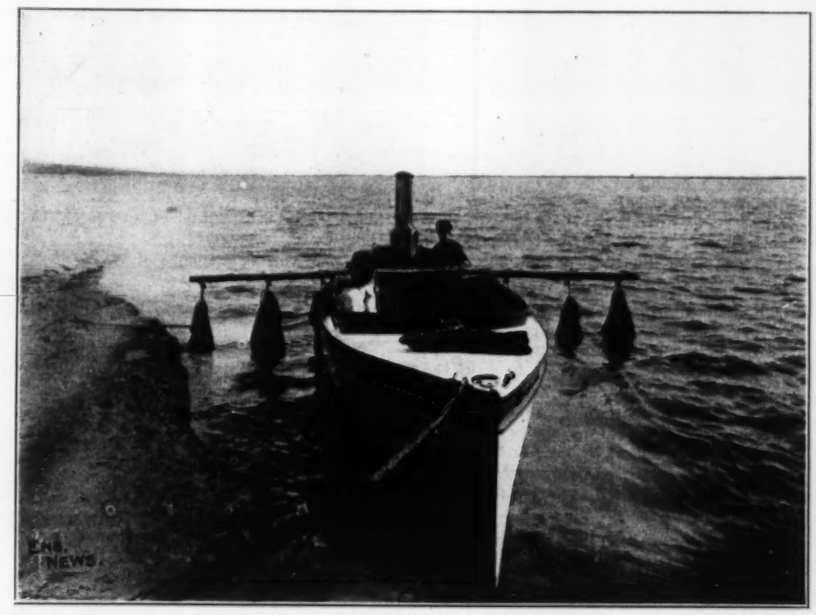
Tests were made for copper in 1,000 c. c. of the sample taken 96 hours after treatment and the reaction was negative. The delicate potassium ferrocyanide test was used. By this test it is possible to detect 1 part of copper in 2,500,000 parts of water.

*Chief Engineer Denver Union Water Co., Denver, Colo.

TABLE I.—RESULTS OF TREATMENT OF SMALL LAKE AT CITY PARK, WITH COPPER SULPHATE.
(Water Treated August, 1905, 10:00 a. m. Strength of Solution 1:2,000,000.)

Microscopical organisms.	Before treatment.	12 hours after.	24 hours after.	48 hours after.	72 hours after.	96 hours after.
Navicula	104	128	152d	124d	No	0
Anabaena, circinnalis	80	0	0	0	samples	0
Anabaena, flos aquae	400	0	0	0	taken.	0
Clathroceptis	16,400	10,400	6,900	3,200d		0
Aphanizomenon	10,000	80	0	0		0
Rotifera	8	0	0	0		24 very small.
Crustaceae	.24g	.24g	.26g	v.f.d.		0
Bacteria per c. c.	6,200	5,900	135,000	130,000		82,000
Temperature C.	24.5°	.....	21.5°	25°		.....
Remarks:	Green surface scum over greater portion of whole lake. Bacillus coli present.	Could not observe; samples taken 10:00 p. m.	Thick scum collected in arm nearest to large lake. Blue-green scum around edges on shore.	Water quite turbid. Surface scum scattered all through lake.	Lake clearing up some. Surface scum practically all gone.	No scum left. Water much clearer.

d = dead.
g = good condition.
v. f. d. = very few dead.



LAUNCH EQUIPPED FOR APPLYING COPPER SULPHATE TO MARSTON LAKE: DENVER UNION WATER CO.

TABLE II.—TABULATED RESULTS OF TREATMENT OF MARSTON LAKE WITH COPPER SULPHATE.

Date.	9/25/05	10/2/05	10/7/05	10/7/05	10/8/05	10/9/05	10/11/05	10/12/05	10/16/05	10/8/05
Microscopical organisms.	Before treatment.	Before treatment.	Treating water. Near boat house.	Treating water. Near South Tower.	1 day after treatment.	2 days after treatment.	4 days after treatment.	5 days after treatment.	9 days after treatment.	Inlet to Marston Lake.
Diatomaceae:										
Asterionella	0	6	8	4	2	4	0	0	0	Encyonema 6
Cyclotella	0	8	8	4	92	104	16	10	4	
Navicula	2	4	0	0	0	0	4	0	0	Nitschia 6
Synedra	590	140	70	80	90	20	0	0	0	
Stephanodiscus	24	112	66	56	64	50	0	0	0	Navicula 100
Chlorophyceae:										
Closterium	0	2	2	2	2	2	0	0	0	
Eudorina	0	6	8	0	6	0	0	0	0	
Pediastrum	0	2	6	2	0	2	0	0	0	
Staurastrum	16	36	34	40	50	46	26	16	0	
Cyanophyceae:										
Anabaena	4,294	2,880	400	40	0	0	0	0	0	
Protozoa:										
Ceratium	172	64	20	2	6	0	0	0	0	
Peridinium	96	84	2	4	0	0	0	0	0	
Rotifera	8	6	8	2	2	0	0	0	0	
Crustaceae	prsnt.	prsnt.	prsnt.	prsnt.	prsnt	prsnt.			prsnt.	
Bacteria, per c.c. at 20° C. after 72 hours	670	720		255		90,000		107,000		
Odor	very grassy	very grassy	grassy	grassy	faint	none	none	none	none	none
Remarks:	Water in lake had blue-green appearance.				Test for copper in 1,000 c. c. was negative.			Water in lake had steel-blue appearance.		

TRACK CONSTRUCTION WITH STEEL LONGITUDINALS ON THE PENNSYLVANIA R. R.

A system of track construction with longitudinal steel girder supports for the rails is to be tried on the Pennsylvania R. R., and is a very remarkable departure from ordinary systems of construction. It is the invention of Mr. Gustav Lindenthal, M. Am. Soc. C. E., of New York, and the construction is clearly shown in the accompanying cuts. Fig. 1 is a general plan; Fig. 2 shows the details of the longitudinals, and Fig. 3 shows the chairs, rail clips and bolts.

It will be seen that each longitudinal is composed of two bulb angles and two Z-bars, riveted together in pairs to form two beams of approximately I-beam section and connected at intervals by riveted diaphragms composed of two angle brackets. These longitudinals are in lengths of 32 ft. 11 ins., or 33 ft. c. to c. of the splices, which are composed of four flat plates riveted to the two vertical webs. Upon the longitudinals are heavy cast iron chairs or seats, 1½ and 2 ft. apart, secured by nuts and clips on bolts having T-heads to fit the narrow slot in the top of each longitudinal. The rails are held by tap bolts with cast steel clips. The ordinary chairs give a 3-in. bearing to the rail, but the chairs under the rail joints are 5½ ins. long on the rail seat. At every fifth pair of chairs (9 ft. and 10 ft. intervals) is a transverse tie-bar, consisting of a flat steel bar bent as shown and bolted to the sides of the chairs. The rails and longitudinals are laid with square or even joints, but the joints of the rails come at the mid-length of the longitudinals and are supported by specially wide chairs, as above noted.

A somewhat similar track construction was designed by Mr. Lindenthal about six years ago, but required the use of bulb angles of special size and design (8 × 6 ins.), two of these angles taking the place of the two riveted members in the present design. This new design has undoubtedly the heaviest longitudinals ever built, as the various foreign systems of steel longitudinals consist usually of a single rolled trough to carry each rail. The longitudinals will be laid upon and embedded in broken stone ballast, but care will be necessary to avoid giving too firm a bearing under the bottom chord as this would tend to free the wider top chord from its bearing upon the ballast. In order to drain the water from the ballast between the longitudinals, a 3-in. cast-iron pipe is passed through the webs of one longitudinal on each 33-ft. section, the pipes alternating on opposite sides of the track.

For the plans of this track construction we are indebted to Mr. Joseph T. Richards, M. Am. Soc. C. E., Chief Engineer of Maintenance of Way, Pennsylvania R. R., who informs us that it will be laid for a length of about 1,000 ft. a short distance east of Pomeroy, Pa., on the Philadelphia Division. It will be on a tangent in one of the freight tracks. The steel work is being built by the Pennsylvania Steel Co., of Steelton, Pa., but the track is not expected to be completed before next summer.

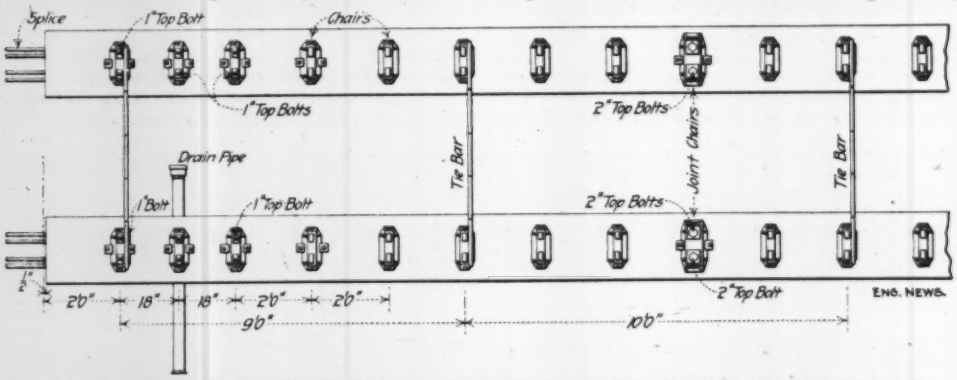


FIG. 1. PLAN OF ONE LENGTH OF TRACK WITH STEEL LONGITUDINALS: PENNSYLVANIA R. R.
Gustav Lindenthal, M. Am. Soc. C. E., Inventor.
Joseph T. Richards, M. Am. Soc. C. E., Chief Engineer of Maintenance of Way.

A RECORD-BREAKING RATE OF RUN-OFF ON SMALL STREAMS AT ITHACA, N. Y.

By E. C. Murphy,* Assoc. M. Am. Soc. C. E.

The flood of June 21, 1905, on Six Mile Creek and Cayuga Inlet, New York, gave the largest recorded rate of flow of any streams of their size in the northeastern part of the United States. While the facts relating to this flood are mainly of local interest, some of them are of sufficient general interest to merit a brief presentation in an engineering journal. A full account will appear in the forthcoming Water Supply Paper of the U. S. Geological Survey on Destructive Floods of 1905.

Six Mile Creek drains an area of 46 square miles; Cayuga Inlet, an area of 95 square miles. Both basins have steep, grass-covered, sparsely timbered, nearly impervious slopes.

The rainfall at Ithaca, and at seven places in the immediate vicinity of these basins, for the 24 hours in which this flood took place, varied from ½ to 1¾ ins. The greatest recorded hourly rate was 0.6 ins. Such rates will only cause a small freshet. The maximum intensity of this storm can only be judged by the maximum rate of flow of the streams and the damage done. These indicate that an exceedingly heavy rain fell on two comparatively small areas; one in the vicinity of Brookton and Slaterville, the other in the vicinity of Stratton.

*Engineer, U. S. Geological Survey, Washington, D. C.

Both streams rose very rapidly on the af[ternoon] of June 21. Six Mile Creek attained a ma[ximum] stage in Ithaca of 10 ft. above low wa[ter] the maximum head on the William's dam w[as] also 10 ft. The stream was out of its banks f[or] about ten hours, and submerged a larger part of [the] city of Ithaca than any previously recorded fl[ood].

The maximum rate of flow of Six Mile Cr[eek] has been computed at two places on it; in Itha[ca] and at the William's dam, four miles above Ith[aca]. At the former place the flow was found from K[utter's] formula to be 8,980 sec.-ft., or 195 sec.-ft. per square mile. At the latter place it was com-puted from the head on the dam, length of crest, etc., to be 8,500 sec.-ft.

Judged from the erosion of the bed and banks the maximum rate in the vicinity of Sla[terville] must have been 300 sec.-ft. per square mile.

The maximum rate of flow of Cayuga Inlet could not be satisfactorily measured on account of change of stream bed. From a gulch of 2.5 sq. miles area near Stratton the writer believes the run-off exceeded 350 sec-ft. per sq. mile.

The four streams that drain the area at the southern end of Cayuga Lake and enter the lake in Ithaca have a drainage of 272 square miles. One of these streams, Fall Creek, with a drainage of 117 square miles, was not in flood at this time. Another, Cascadilla Creek, did not overflow its banks. Some of the tributaries of Cayuga Inlet were not exceptionally high. The most destructive flood on these streams, therefore, in the past 50 years, was caused by a storm that covered less than half this drainage area.

Rainfall records are of little value in estimating the maximum rate of run-off of streams, especially the smaller ones. These maximum rates are due to storms of short duration and great intensity over small areas, and there is seldom a rain gage in the area of greatest precipitation. The maximum rate of flow of Six Mile Creek at Ithaca, June 21, 1905, was about three times greater than its supposed maximum rate computed from rainfall records.

The natural, crooked waterways of the smaller streams of quick spilling basins are entirely inadequate to carry off the occasional very large flow on them without overflow, and consequent loss. The channel should be straight, and widened, if necessary, and the banks protected from erosion in cities and villages, and in the vicinity of railway crossings. The loss due to floods on such streams will, in a few years, more than pay the cost of such improvements.

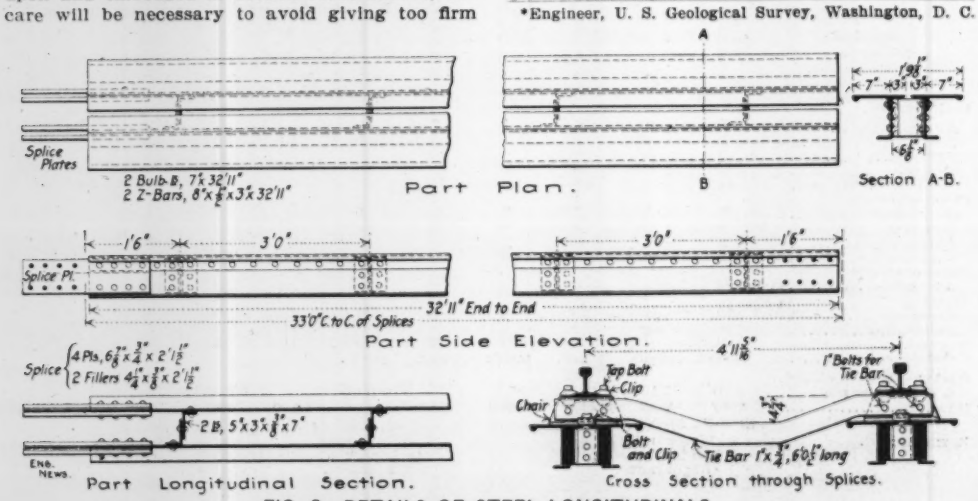


FIG. 2. DETAILS OF STEEL LONGITUDINALS.

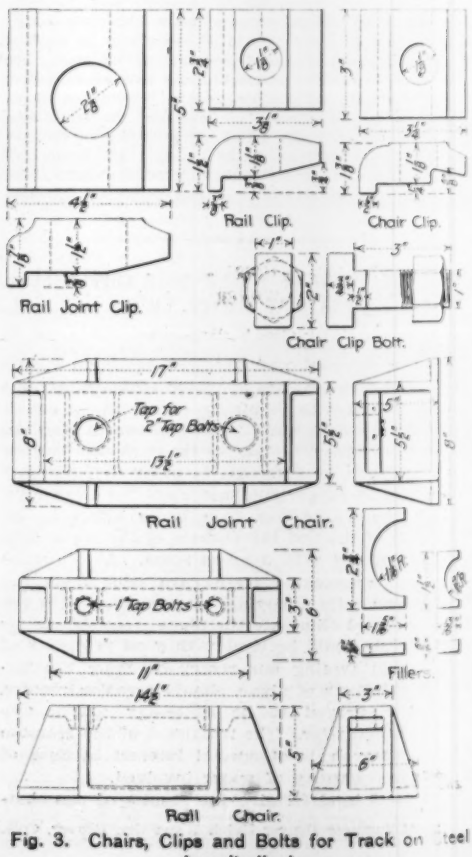


Fig. 3. Chairs, Clips and Bolts for Track on Steel Longitudinals.

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The latest reports from Washington indicate that the question of the type of canal to be built at Panama will not be brought before Congress by the Executive when it reassembles. Under the provisions of the Spooner Act, the President has full authority to proceed with the construction of a lock canal at Panama, as recommended by the Isthmian Canal Commission of 1901. Were it necessary to change to the sea level plan, involving a much larger expenditure and a longer time for construction, a resort to Congress would be necessary. The division of opinion in the Advisory Board over the type of canal, is likely, as was noted last week, to turn the question of the type of canal over to the Canal Commission itself for decision and that body is understood to strongly favor the lock canal.

On the other hand Congress is likely to undertake a general investigation of Panama Canal matters and this will very likely be made to include the question of the type of canal to be built. The interests which are fighting for delay on the canal work will unite in favor of the sea level plan and with them will, of course, be a certain number who will honestly believe in the sea level canal as the best plan.

For those of our readers who wish to post themselves as to the comparative merits of the two types of canal and the great engineering questions which have arisen at Panama, we strongly commend the series of papers by Mr. Wm. Ham. Hall, M. Am. Soc. C. E., of California, begun in this issue. Mr. Hall writes with a thorough knowledge of the situation and with none of the restrictions which at times prevent the official reports on the Panama situation from telling the whole story.

We published in our issue of Oct. 26, a warning issued by the Reclamation service to contractors bidding on Government work explaining that as the letter of the specifications would be enforced, contractors should beware of bidding low on contracts and relying on the leniency of the engineers in charge to save him from loss.

In illustration of the need of such warning we are informed that the contractors who are engaged on the Reclamation service work, and particularly those from the East, are having a pretty hard time.

There have been in the past few months numerous developments in railroad building, and every competent subcontractor has more business than he can handle. The main contractors as a rule depend upon these men for the actual performance of work, and several of these big contractors, relying upon their ability to pick up competent subcontractors or foremen, have been bitterly disappointed to find when the contract was awarded to them that these men were already employed by the big railroads or by their competitors.

As the eastern contractors are becoming better acquainted with the conditions, they find a number of obstacles which they had not anticipated. The country is sparsely settled, and the shrewd settlers hold up the contractor to the very last dollar, whether it be for camping place, temporary road, or use of pasture. Prices double or triple the value of the property are usually demanded.

On much of the contract work done for private companies, the contractor has been able to secure concessions, as to the quality of the work required, by granting favors as to time of payment etc. Thus has grown up a habit of considering the specifications as merely a general set of requirements and not a hard and fast part of the contract agreement to be rigily enforced. On the Reclamation work, the engineers are insisting on absolute compliance with the specifications; and contractors who have bid too low have in several instances been obliged to forfeit their contracts. This is notably the case in localities where the labor market has been constantly depleted and the cost of materials has suddenly increased.

An interesting court decision on a proposed public contract is printed in full on another page, together with such extracts from the contract form and specifications as we believe are necessary to explain the decision. We doubt not that the decision will be widely read. If upheld on trial or appeal it will set a precedent of great importance for public contracts. It will render difficult or impossible any provision for "extras" on the account of increased quantity or changed quality of work or materials. Not that the Court denies that changes may become necessary in the course of execution of a large contract: On the contrary that necessity is distinctly recognized. But the decision says, in substance, that such changes are adequately covered by that clause of the contract which provides for changes in work without change of cost. It follows that the Court believes other changes, that is such changes as do involve increase of cost, to be illegal, unless the work under such changes be regularly advertised and bids asked—a proceeding which is possible only in the rarest of cases.

Whether it is feasible, or desirable and practicable, to carry out a public works contract involving several million dollars without modifications extensive enough to change the cost of the work need not be here discussed. It will be apparent, however, that if any class of work favors the exact drawing of plans and specifications, and their execution without change or increase of cost, bridge construction is such work. Probably courts will not be inclined to make a distinction between one class of work and another, as to feasibility of working without change or increased cost, so that a precedent set in a case of bridge work may easily be applied by other courts to excavation, foundation work, and the like where unknown conditions and many risks face the contractor.

It may be, however, that the decision of the Court in the Manhattan Bridge case was influenced less by the general clauses criticized than by the ambiguous alternative specification for nickel steel and high carbon steel, for nearly 10,000 tons of riveted work. It is a fact that the specification and contract form do not make clear who is to decide which of the two materials shall be used. The view might be taken that the bidder is to exercise his choice in making the bid, which would mean that he would have to submit two bids, as the bidding sheet does not provide for alternative figures. It might be held that the bidding form requires the bidder to set a price for which he would furnish either material, at the option of the Department of Bridges. Or it might be held that the bidder, while making but a single bid without indication of his choice of material, reserves the right to furnish either the one or the other, as he may find most convenient. The possibility of such conflicting views suggests that serious dispute might arise, during the execution of the contract, as to the intended meaning, especially as the two materials would differ in required quantity, in unit cost, and in total cost.

The object of the alternative specification is not involved in mystery, and in the abstract it is rather a laudable object. A material, nickel steel, was in view by the engineers of the Department of Bridges, which offered specific advantages over ordinary carbon steel, but whose commercial availability in large quantities and under rigid tests was somewhat doubtful, if the cost was to be within reason. The use of ordinary low or medium carbon steel was almost out of the question, as it would have made very difficult details. But high-carbon steel, whose use for the main truss members was in this bridge wholly unobjectionable, was available as an alternate to nickel steel. By drawing a specification to cover both materials, and calling for a bid to cover both, it was thought that opportunity would be given the contractor to explore thoroughly the practicability of obtaining and furnishing nickel steel to meet the specified conditions, and that he would thus be able to work out, with virtual certainty of success, the technical and commercial problems which stood in the way. But such a purpose, however, proper and admirable in the engineer of a private purchaser, must, apparently, not be held by an engineer in public employ, nor expressed in a public contract. The opinion of the Appellate Court on this point will be awaited with interest.

THE HYDRAULIC FEATURES OF THE LATEST NIAGARA POWER PLANT.

The new Niagara power plant, whose construction is described in this issue and the issue of Nov. 9 of Engineering News, commands attention in several important particulars. The difficulties of construction were unusual; the design is bold, and in several respects is distinctly novel; the work is being carried to completion with a more rapid progress than that of any previous Niagara power plant of corresponding size, and, when completed, the cost, it is confidently asserted, will be less per unit of power developed than in the case of any of the other Niagara power plants of the first magnitude. It is particularly the novelties in hydraulic design, however, that come up for discussion in the articles that are noted above, and it is with these alone that we shall concern ourselves here.

Two types of hydraulic construction have been developed for utilizing the falls at Niagara. In the older of these types the water taken from above the falls and carried along shore by pipes or canal to the crest of the cliff below the falls, is discharged downward through vertical penstocks to the wheels in a power house located at the foot of the cliff. This type is represented by the plant of the Niagara Falls Hydraulic Power Manufacturing Co., the oldest of the larger power plants at Niagara, and by the plant of the Ontario Power Co., now under construction on the opposite and Canadian side of the river. In the second and newer type, and the type peculiar to Niagara, the water, taken from the river above the falls, is dropped through vertical penstocks to wheels located in a deep pit in the rock, and then discharged by tunnel from the bottom of the wheel pit to the gorge below the falls. This type is represented by the plants of the Niagara Power Co., and its offshoot the Canadian-Niagara Power Co., and by the plant to whose construction we refer particularly here.

Regarding the new plant then it is to be observed first that the type of hydraulic design employed follows precedent. Such novelties as it presents are novelties of detail in the arrangement and design of the several parts. It is in respect to these details alone that it comes before engineers for judgment.

First to be considered is the character of the novelties. In the older plants the wheel pit is a continuation of the tailrace tunnel; it may be, without great error, considered as a section of the tailrace tunnel with the roof removed. In the new plant the wheel pit is a water tight enclosure

separate and distinct from the tailrace tunnel. In the older plants the turbines, suspended above the pit bottom, discharge directly into the wheel pit, and its bottom is always flooded except when all the turbines are shut down. In the new plant the turbines, set directly on the pit bottom, discharge through draft tubes piercing the walls which separate the wheel pit from the tailrace, and the wheel pit is always dry. In the older plants the tailrace lies to one side of the wheel pit and connects with it by a branch tunnel. In the new plant the tailrace tunnel is forked with a branch along each side of the wheel pit; half of the draft tubes have their outlet into the left-hand branch and half into the right-hand branch.

In respect to the headworks arrangement the new plant differs essentially from the two older plants. In the latter the collecting and impounding structure is, on the American side, a canal extending inshore normally to the river bank, and, on the Canadian side, a narrow entrance channel widening out into a broad inshore basin. The forebay works of the new plant are entirely outshore structures; the power house itself is set on the brink of the river and forms with its walls a part of the river bank.

The preceding comparison is necessarily brief and is confined to certain principal structural parts, but it indicates clearly enough the radical departures in detail from the precedents set by the older wheel pit works. The natural presumption is that these changes were made because certain advantages were expected to be gained from them. Let us see what these advantages seem likely to be.

By excluding the tailrace water from the wheel pit the engineer obtains a compartment for his turbines that is accessible in all parts at all times. Such work as has to be done about the wheels is done absolutely without hindrance from water. Another advantage of the design which will appear under certain rare conditions, is that it prevents any possibility of the turbines ever being submerged. It has occurred that ice jams in the river below the falls have caused an increase of more than 50 ft. in the ordinary high water level of the lower river. If this condition should occur the only effect it can have in the case of the new plant will be a reduction of the operating head, the water cannot back up into the tailrace tunnel and submerge the turbines.

The foregoing are the minor advantages of the independent wheel pit, the chief advantage is that it permits the turbine foundations to be placed directly on the rock bottom of the pit. In the older plants the wheels are carried by a steel beam platform built across the pit and rest on their draft tubes on this platform, this construction being necessary to raise the wheels above the tailrace water in the bottom of the pit. It will be seen at once that this construction requires a deeper pit for a given head of water on the turbines than does the construction employed in the new plant. A more important advantage of the new construction, however, is that a rigid foundation is had to absorb vibrations. Vibration is a rather serious matter in a vertical shaft 115 ft. long, with a 13,000-HP. turbine at one end and a dynamo of corresponding size at the other end, when this shaft is revolving at 250 revolutions per minute under fluctuating load, and the thought given in the design of the new plant to minimizing vibration is deserving of attention. Not only are the wheels given the most rigid foundation possible, but the shaft bearings at intermediate points and the dynamo foundations are very heavy concrete arches set into the solid ledge rock.

The forking of the tailrace tunnel so that it straddles the wheel pit divides the turbine plant into two groups of units entirely independent of each other. There are virtually two power plants in one. Either plant may be shut down without interrupting the work of the other. Frequent and thorough inspection of every portion of the turbines and their connections is possible, and repairs even to the extent of replacing half of the working units, can be made with a sacrifice of only a part of the power-producing capacity of the plant. Compared with the construction in the older plant the forked tunnel arrangement of course increases the amount of tailrace excavation, but this is partly compensated for by the shallower wheel pit required where no provision has to be made in the pit for the tailrace water.

Incidentally to the main question just spoken of, mention may be made of the crooking of the draft tubes so that they discharge at the bottom of the tailraces and in a direction parallel to the tunnel axis. Experiments with models made by the engineer showed that by this arrangement the water got away much faster than when the draft discharged across the tunnel. The explanation made is that the cross discharge creates eddies and currents which back up the water.

The difference in the character of the headworks for the new and the older plants has been noted. This difference in principle and plan necessitated wholly different considerations in the designing. Incidentally, it may be remarked also that it entailed far greater constructional difficulties.

The limiting factor in the success of Niagara power is the ice problem. Cake ice in enormous quantities floats down the river for weeks at a time from the lakes above and mush ice is formed in the turbulent rapids primarily by the freezing of the spray and foam, and secondarily by the disintegration of cake ice. To prevent this floating ice from banking up in front of the penstock screens is a problem of great difficulty at all of the Niagara power plants; in fact, in all of the plants yet put into operation the winter months inaugurate a continuous and costly struggle against ice.

In the plant under consideration the problem has been how to pocket the water and lead it to the penstock gates without bringing the ice with it. The design adopted attempts the solution as follows: the gathering works are planned so as to give the least possible obstruction to the surface currents and diverting booms are interposed to screen off the surface currents and the ice carried with them. Just how far the plan will succeed in its purpose not even the engineers are inclined to prophecy. Certainly, however, it presents a well-studied attempt to solve a difficult problem and the result will be watched for with more than usual attention.

Altogether the design of the latest Niagara power plant shows in comparable parts a determined attempt to improve on its predecessors. In some respects, however, the most striking characteristic of the design is its boldness. A proposition to cofferdam the Canadian rapids above the falls, and to drive a tunnel under these rapids to an outlet in an unknown cliff face behind the great cataract was not one to be entered upon lightly. There was ocular evidence that the builders would have their work cut out in damming the rapids, but even here there were no definite data to base calculations upon; the depth of water and the character of the bottom were both unknown. It was something, however, to know the general character of the task ahead; even this knowledge was denied when it came to planning the tunnel work. To challenge the unknown but always possible difficulties of the cofferdam and tunnel work required no small degree of courage on the part of the men who lent their bank accounts to the task as well as on the part of the engineers.

AN EXPERIMENT IN THE IMPROVEMENT OF RAILWAY TRACK.

The structural and economical defects of the present type of railway track, as a structure for carrying a traffic of heavy, fast and frequent trains, are frequently discussed and more or less generally acknowledged. Practically nothing has been done, however, towards improving the conditions by introducing any new type of construction, the improvements being simply in the line of making the parts of the present type heavier and more substantial, substituting concrete or steel ties for wooden ties, and giving more care to the maintenance of track. For these reasons an experiment in steel track construction which is to be tried on the Pennsylvania R. R. is of rather exceptional interest, especially in comparison with the proposed concrete roadbed or track construction described in our issue of Nov. 2. The experimental track for the Pennsylvania R. R., which is illustrated in another column, consists essentially of a steel longitudinal girder under each rail, but the rails have not a continuous bearing, being supported by chairs about 3 ft. apart. Each longitudinal (in 33-ft. lengths) is composed of four main members, put together with two rows of rivets, connected by riveted diaphragms, and having riveted splice plates. Heavy cast-iron chairs are bolted to the longitudinals, and to these the rails are secured by tap bolts and clips, while at intervals there are transverse tie bars bolted to the chairs. The amount of steel in the number of parts, and the amount of riveting work seem to put this construction out of the field of practical track work, unless it can be very materially simplified. This girder construction will not have a rigid support but will be embedded in broken stone ballast, and the inventor is reported as considering that concrete is liable to disintegrate and will not permit of any necessary leveling up or surfacing of the track. Particulars of the weight and cost are withheld at present, but when this system was first suggested, some six years ago, the weight was given as 107 tons per mile, with a bearing area of 200 sq. ft. per rail length of 60 ft., as compared with 140 sq. ft. for the usual cross tie construction. The greater stiffness would of course be a much more important advantage than the mere increase in bearing area. In this original design, however, two rolled shapes of special section took the place of the two built-up sections in the present design, and these would no doubt be eventually used if the track should be put on a commercial footing. The cost of the track as originally designed (avoiding the use of riveted or built-up members) was estimated (in 1899) at $14,368 per mile of completed single track, but the enormous amount of riveting in the present design will undoubtedly increase the cost materially. The track construction with concrete roadbed described in our issue of Nov. 2 is estimated to cost $14,000 per mile, as against $6,000 for the ordinary type of track.

Longitudinal supports for the rails are as old as railways themselves, beginning with timber beams (which continued in actual main line service in England until a few years ago) and developing into various forms of iron and steel construction. Metal longitudinals have never been regarded with favor for modern track construction in this country, and have (we believe) never been used except in the case of an experimental track described in Engineering News, of April 28, 1904. In 1891, the late Thomas C. Clarke presented a paper before the American Society of Civil Engineers in which, after setting forth the weakness and defects of the ordinary railway track, he advocated the adoption of longitudinal bearings and suggested for this purpose a type then in extensive use in America. The use of metal longitudinals is now confined almost exclusively to Germany and Austria. It is to be noted that in many cases the designs in use there are the invention of railway engineers and officers in high position. It was at one time thought that with a continuous longitudinal bearing a lighter weight of rail might be used, but this did not prove to be the case. The rail not being integral with the longitudinal and being secured to it at intervals only, was found to have a wave motion (increased as the weight was reduced) causing wear of the bearing surface of the longitudinal. At any rate this argument would not apply to the system to be tried on the Pennsylvania R. R., as the rail has not a continuous bearing.

From statistics given in two reports, on the use of metal track construction, issued by the United States Government, we have compiled the following summary, which shows practically no increase in the use of longitudinals between 1889 and 1894, while the use of other metal track supports increased materially. It is doubtful if there are over 3,000 miles of this system now in use, and all of this is in the two countries above mentioned:

	1890. Miles.	189 Mil
Metal track:		
Longitudinals	3,637	3
Bowls and plates	10,013	12
Cross ties	11,059	18
Total metal track	24,803	34
Total track	361,886	389

In practically all these foreign cases the longitudinals are rolled troughs, of varied cross-sections, and have the rails resting upon and bolted or clamped to them, so that the rails have a continuous bearing. A special point to be noted is that in very many of these designs, the longitudinals are supplemented by heavy cross ties (usually of similar section to the longitudinal), upon which the longitudinals rest, and to which they are secured by riveted connections. These ties unite the two longitudinals into one homogeneous construction and serve to distribute the load over the ballast. The design to be tried on the Pennsylvania R. R., however, differs in three essential respects from the usual style of track construction with longitudinals: First, It employs a heavy built-up and riveted girder instead of a single rolled section; second, it does not give a continuous bearing to the rail (which is supported at intervals by chairs); third, it has no heavy cross tie connections beneath the longitudinals, but has simply tie-bars bolted to the rail chairs, so that each line of longitudinals must carry its own load. It is easily supposable that in the broken stone ballast one longitudinal may settle occasionally and require to be raised to bring the rail to the proper surface.

The Pennsylvania R. R. experiment is an interesting one, and is to be tried on a sufficiently large scale and under sufficiently heavy traffic conditions (1,000 ft. of main line freight track) to give fairly definite results. Whatever its practical success or value may be, however, it would seem that some simpler system must be devised before we can arrive at a practical solution of the problem of how to improve (within reasonable limits of cost) the construction of railway tracks carrying heavy traffic with heavy wheel loads and at high speeds.

LETTERS TO THE EDITOR.

The Wind Gage on the Leven Viaduct, Furness Ry.

Sir: In your issue of June 1, 1905, p. 576, I note you refer to the wind pressure danger signal on the Furness Railway Co.'s Leven Viaduct in Scotland. This is, of course, incorrect, as the Furness Ry. runs to Barrow-in-Furness, and the Leven Viaduct is over the River Leven in Lancashire, which discharges into Morecambe Bay, and has no connection with Leven in Scotland.

Yours truly, R. L. Chambers.

41 Albury Park Road, Tynemouth, England.

Location of Railway Lines to Secure a Monopoly.

Sir: Referring to the article, "The Value of a Railroad Location That Shuts Out a Competitor," in your issue of Nov. 9, 1905, below please find extract from an Act of Congress approved March 3, 1875:

Sec. 2. "That any railroad company, whose right-of-way, or whose track or roadway upon such right-of-way passes through any canyon, pass or defile, shall not prevent any other railroad company from the use of said canyon, pass or defile for the purpose of its road, in common with the first road located, or the crossing of other railroads at grade, and the location of such right of way through any canyon, pass or defile shall not cause the disuse of any wagon or public highway now located therein, nor prevent the location through the same of any such wagon road or highway where such road or highway may be necessary for the public accommodation."

Yours truly,

S. A. Wallace, Jr. M. W. S. E.

607 Woodberry St., St. Paul, Minn., Nov. 20, 1905.

(The above is a part of Chapter 152 of the Acts of the 43d Congress, 2d Session. It relates only to railway rights of way through the Public Lands of the United States.—Ed.)

A Hint to Contributors.

Sir: In examining the always well executed illustrations in Engineering News, the thought occurs that whenever some familiar object is included in the picture —a man, boy, dog, tool, etc.—such an object serves as a scale by which to measure other objects in the picture. In the absence of any such familiar object it is often difficult to estimate sizes. This seems a small matter, but may be important enough to merit attention.

Very truly yours, T. G. Dabney.

Clarksdale, Miss., Nov. 10, 1905.

The hint is an excellent one. We are well aware of the usefulness of familiar objects as a scale in photographs; but a very small percentage of the views published in Engineering News are from photographs taken by direction of our own staff. We are confined to choice of such photographs as contributors and others send us. If those who take photographs of machinery, buildings, etc., for industrial concerns, will take care to include always some object of familiar size in the picture, the end referred to by our correspondent will be secured.—Ed.

Are the Right Bank and the Right Fork of a Stream on the Same Side?

Sir: In regard to the inquiry of H. M. P. as to which is the right bank and fork of a stream, you have given two correct answers that the right bank is to your right as you proceed downstream. No reply has been given as to which is the right *fork* of a stream, and it is quite probable that nearly every one would reverse the rule for bank, and look upstream when taking the right fork. Is this correct? B. P. Thomas.

(We referred the above inquiry to Mr. F. Hodgman, of Climax, Mich., author of a well-known treatise on land surveying, and append his reply, as follows.—Ed.)

Sir: I do not happen to have met with any authorities as to what constitutes the right fork of a stream. In fact, I think the term is not generally used, but the words north, south, east or west used instead. The nearest thing I have on the subject is found in Webster's Dictionary, which gives as one of the definitions of the word "right," "Being on the right hand of a person whose face is toward the mouth of a river."

Yours, F. Hodgman.

Climax, Mich., Nov. 15, 1905.

Some Notes on the Development of Eye-Bar Manufacture: Corrections.

Sir: In Mr. J. H. Springer's communications published in Engineering News of Aug. 17 and Nov. 2, 1905, under the above title, there are certain errors which require correction, in addition to the corrections made by Mr. C. P. Buchanan.

Reference is made to two patents for improvements in eye-bars, one taken out by Mr. Springer and the other by the writer. Mr. Springer states that the writer's specifications and claims were the same as his. Any one who is interested and will look up the specifications and claims of the two patents will find that this is not the case. The difference is stated by Mr. Buchanan in his communication; viz., whereas Springer used a continuous bar bent around the end of the main bar, the writer used two side bars and allowed the main bar to run to the end. The purpose of this modification was to cheapen the cost while losing none of the advantages of side piling, if advantages there were. Mr. Springer states that Mr. Gottlieb, then president of the Keystone Bridge Co., "wanted the eye-bars of the Dayton Bridge made under the Springer patent," and that the writer had made the change in the drawing-room on his own responsibility. This, again, is incorrect, but is of no importance. Mr. Buchanan correctly states the case in saying: "The management felt so sure that the Strobel process would be equally efficacious, and of course cheaper, that this method was followed instead of the one for which permission (by Mr. Becker) had been given." The writer at the time was assistant to the president and engineer of the company.

These methods of making eye-bars by side piling were devised in 1882 and 1883, at a time when the change from wrought iron to steel was taking place in the building of bridges. Previous to that time eye-bars had been extensively and successfully made at the Keystone Bridge Works in iron, by the cheaper method of top piling, i. e., the required stock for making the head was obtained by piling one or two short pieces of the bar on top and at the end of it. This method did not prove satisfactory in steel. It was thought that the Springer process would give better results and some tests made of it were promising. Tests were made of the writer's process which did not give satisfactory results. This may have been because the steel used was deficient in welding qualities, or because the side pieces were not held firmly against the edges of the bar in forging. The latter defect could have been remedied, but the former defect, the deficient welding qualities, was true of the steel of that day and could not be remedied. That steel, made either by the acid open-hearth or the Bessemer process, was by its nature harder than the basic open-hearth steel now generally used, and it was very variable in the degree of hardness and in other qualities. This variation was partly the fault of the makers of the steel blooms and billets, but was also due to defective heat treatment at the mills. It must be remembered that the heating and rolling into the finished bar were then done at *iron* mills by men who had had little or no experience with steel, and the reducing was done in rolls that were suitable for rolling iron but not adapted to the rolling of steel.

Further experiments with either of these processes for making eye-bars by side piling were at this time discontinued because the management of the company concluded, and no doubt wisely, that dependence could not be placed upon the steel then available to give a reliable weld in all cases. It was decided to make all steel eye-bars in future by upsetting, and steps were taken to equip the plant with the necessary facilities to that end. Mr. Buchanan correctly states that "The Keystone Bridge Co. never made another attempt to manufacture eye-bars of steel under either of these patents."

C. L. Strobel, M. Am. Soc. C. E.

Chicago, Nov. 17, 1905.

Notes and Queries.

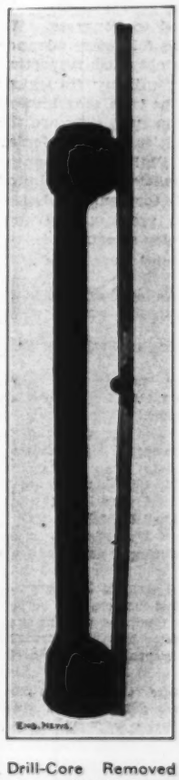
Information is wanted by a reader concerning the use of iron poles for telephone wires. Where are they used, under what conditions are they necessary or desirable, and what are their disadvantages?

Mr. J. W. Schaub, of Chicago, sends a correction to the article published under his name in our issue of Nov. 2 as follows:

Referring to the screw-spike adopted by the South Side Elevated Ry. in Chicago, the writer stated that this spike is now being manufactured by the Oliver Iron & Steel Co. This is true, but he now learns that this spike was first made in this country by the American Iron & Steel Manufacturing Co., of Lebanon, Pa., and that they furnished the screw-spikes to the South Side Elevated railroad. The article leaves the reader under the impression that these spikes were supplied by the Oliver Iron & Steel Co., which is an error, they having only furnished a sample.

A ROTARY DRILL CORE FROM A STEEL I-BEAM.

The accompanying illustration shows, we venture to say, the most remarkable core ever taken from a core drill. It is a view of the section of steel removed from a steel I-beam by a Davis Calyx Core Drill working on the site of the proposed new Plaza Hotel, at 59th St. and Fifth Ave., in New York City. Drilling has been in progress for some time on this spot to determine the depth of rock preparatory to making the foundation plans of the new building. To account for the steel beam being encountered it is proper to say that the site was formerly occupied by the (old) Plaza Hotel, and that the drill holes in many cases passed through the old building's foundations.



Drill-Core Removed from a Steel I-Beam.

In respect to the particular hole producing the steel core, it may be stated that on July 24, the drill, after penetrating about 15 ft. of earth and debris, encountered a substance harder than anything previously struck. After drilling some time, the usual attempt was made to break off and withdraw the core; but the substance resisted all efforts to break it. Drilling was resumed, interrupted by repeated futile efforts to break off the core, and the next day the drill penetrated to softer material and the obstinate core was drawn up. It was found to be a portion of a 24¼-in. steel I-beam. The drill had struck fair on the top flange and had cut square through flanges and web, taking a core 2⅝ ins. in diameter. The removal of this steel core occupied a day and a half, but the actual drilling, it is stated, occupied only about eight hours, the remainder of the time being spent in fruitless efforts to break off the core.

The machine employed was a standard Davis Calyx Core Drill, built by the Ingersoll-Rand Co., and owned and operated by the Lawyers' Title Insurance Co., of New York city. The machine was fitted with the ordinary Davis shot bit, and the core was cut by chilled iron shot fed

through the hollow drill rods. It is stated that the bit emerged from this severe ordeal with no injury and ready to continue boring. It may also be noted that in the same hole three iron plates were encountered and penetrated; two were 1 in. thick each and one was ½ in. thick. For the information from which this description has been prepared we are indebted to the Ingersoll-Rand Co., of New York city.

AN OFFICIAL INQUIRY INTO THE TERM OF STREET RAILWAY FRANCHISES.

In the State of New Jersey there has been a public agitation during the past year for some limitation upon the granting by municipalities of perpetual franchises to the corporations using city streets. In opposition to the plea for limited franchises, it has been argued on behalf of the street railway companies that they would be unable to sell the bonds to finance the construction of the roads if their franchises were not perpetual. The absurdity of this claim will be evident to most engineers; but it may be of interest, nevertheless, to learn what is the general practice of the principal cities of the United States with respect to the duration of municipal franchises granted to street railway companies.

At the last session of Congress a Senate Resolution was adopted directing the Commissioners of the District of Columbia to obtain and have ready at the opening of the coming session information showing for each of the cities of the United States with a population of over 200,000 the current restrictions under which franchises are granted to street railway companies, together with the basis of taxation and the degree to which the companies are supervised or controlled by State or municipal authorities.

This information has been gathered and will soon be printed and presented to Congress. We are able to present below the following advance summary of the information obtained respecting the length of term of street railway franchises in the several cities. It will be seen that instead of perpetual charters being the rule, they are the rare exception. The large cities of New Jersey and the unfortunate city of Philadelphia appear to be the only large municipalities of the United States where it is still possible for venial or ignorant municipal authorities to grant a perpetual franchise for the use of the city streets.

BALTIMORE.—Charters are granted for a period of 25 years.

BOSTON.—Franchises granted by local authorities are revocable by these authorities with the approval of the State Railway Commission.

BUFFALO.—Last charter, granted in 1895, was for a period of 66 years.

CHICAGO.—Fixed by ordinances. Twenty years seems to be a usual limit when expressed. Under the new law no further franchises will be granted.

CINCINNATI.—Charters are granted for a term of 25 years. The Cincinnati Traction Company, a consolidation of various street railway companies, has a franchise good for 50 years, from April 22, 1896, under what is known as the "Rogers Law," an act passed by the legislature of the state of Ohio on April 22, 1896.

CLEVELAND.—This city grants franchises to street railway companies for operation during a period of from 20 to 25 years.

DETROIT.—Franchises are for a term of 30 years.

DISTRICT OF COLUMBIA.—The charters are perpetual—that is, they are granted by Congress without limitation as to the period of the charter but the reservation of the right to alter, amend or repeal is made in the charter.

INDIANAPOLIS.—By state statute, cities of the class to which Indianapolis belongs are authorized to grant charters to railroad companies for a term not to exceed 34 years.

JERSEY CITY.—The question of street railway franchises in Jersey City is at present under discussion. The charters of street railway companies now in existence were granted in perpetuity with the exception of one subsidiary line of the trolley company which was limited to a period of 50 years. The present agitation is to limit franchises to 25 years.

LOUISVILLE.—The term of a city railway franchise is 20 years.

MILWAUKEE.—Only one corporation operating a railway in the city. The charter of this company is granted for a period of 34 years.

MINNEAPOLIS.—Not given.

NEWARK.—Franchises granted are perpetual. The various companies have been merged and are controlled by one corporation, known as the Public Service Corporation of New Jersey.

NEW ORLEANS.—Term of franchises vary under different ordinances, but as a rule it is for a period of 50 years.

NEW YORK CITY.—By the charter of the city no franchise can be granted by the board of aldermen for a longer period than 25 years, but such grant may at the option of the city provide for giving to the grantee the right, on a fair revaluation, to renewals not exceeding in the aggregate 25 years.

PHILADELPHIA.—The charters are usually perpetual, 999 years.

PITTSBURG.—Franchises are granted by ordinance of the city council and differ in each case so that it is stated that it is impossible to give information as to terms of such charters.

SAN FRANCISCO.—Franchises are for a term not to exceed 25 years. Franchises are granted after open competition and awarded to the company offering the highest percentage of gross receipts arising from the use, operation, possession or enjoyment of the franchise for which such application was made. But no award shall be made, nor any such application granted, unless the stated percentage offered to be paid for the franchise shall be at least three per centum of such gross receipts during the first five years of the period for which the franchise is to be granted, four per centum of the gross receipts during the next succeeding ten years, and five per centum of the gross receipts during the next succeeding ten years.

ST. LOUIS.—The franchises are granted by the municipal assembly. In each case there is a specified number of years for which it is granted.

THOMAS J. LONG.

Mr. Thos. J. Long, M. Am. Soc. C. E., Vice-President of the Atlantic, Gulf & Pacific Co., died in New York City on Nov. 20, after a brief illness of pneumonia.

Mr. Long was born in New York City, January 20, 1852, and was a graduate of Rensselaer Polytechnic Institute at Troy, N. Y., in the class of 1873.

After leaving college he was first employed in engineering work on the Atlantic & Great Western R. R., and afterwards from 1874 to 1885 he

Thos. J. Long

occupied various positions, but very soon went to the Department of Docks, of New York City, where he was engaged for 11 years, from 1874 to 1885. He steadily advanced, and when he left the Department at the age of 33, he was Assistant to the Chief Engineer of the Department.

He next went to the Morse Bridge Co. of Youngstown, Ohio, and remained there until the destruction of the works by fire and the dissolution of the company in 1887. From that year until 1896 he was connected with the Union Bridge Co., of New York City, as General Agent and had charge of the construction of several of the largest bridges in the West, notably that across the Ohio River, at Cairo, Ill., and the Merchants' Bridge at St. Louis, Mo.

From 1896 to 1898 he was engaged in general practice as a Civil Engineer and Contractor, and was interested in the enlargement of the Erie Canal.

From 1898 to 1900 he was associated with the firm of R. P. & J. H. Staats, as Vice-President, doing a general engineering and contracting business, with a specialty of dock and harbor work.

From 1900 until his death he was Vice-President of the Atlantic, Gulf & Pacific Co., and closely associated with its President, Mr. George W. Catt, notice of whose death appeared in our issue of October 12.

He made three professional visits to South America, making special studies along engineering lines, and covering the principal cities of the East Coast, and along the Amazon to the Rio Negro. He also visited Quito and other points in Ecuador.

He invented and patented a self-registering tide and reservoir gage which has been largely used by Government engineers and by water companies.

He belonged to the Century, University and Engineers' clubs, as well as to the American Society of Civil Engineers and the American Geographical Society.

He was married in 1882 to Ada Louise Rideau, of Staten Island, who died the following year.

Of the widest travel and engineering experience and possessing immense and valuable engineering data collected by himself, and most conveniently arranged, Mr. Long was even more prominent as a courteous and able executive of important works, especially in those directions where engineering ability needs to be supplemented by a wise diplomacy and gentlemanly address. Mr. Long was deeply interested in literature, and besides the acquisition of an extensive engineering library, he made one of the most valuable private collections of Americana in this country. The engineering portion of this valuable library is left by his will to the American Society of Civil Engineers, while the literary portion will go to the Century Club of New York City.

Mr. Long's wide circle of friends will remember him as one whose unfailing good nature and charm of address, no less than his professional eminence, made him welcome in every circle of engineers.

DECISION AGAINST THE PROPOSED CONTRACT FOR THE MANHATTAN BRIDGE.

As noted briefly in our last issue (p. 539), a decision was rendered on Nov. 21, 1905, by Justice Dowling, of the New York State Supreme Court, restraining the City of New York from entering into a contract with the Pennsylvania Steel Co. for the construction of the superstructure and the metal work of the anchorages of the Manhattan Bridge, over the East River, in New York City. The direct result of this decision is of great interest to the city of New York, as it threatens to postpone for an indefinite period the beginning of work on this important bridge. Wider circles, however, are interested in the reasoning on which the decision bases, and its relation to public works contracts generally. While the decision is not that of a court of last resort, it is yet of sufficient weight to merit recording in full at this place.

Broadly, the decision was rendered on two grounds: 1. That certain "general clauses" or contract provisions, whereby the manner of ordering and adjusting "extras" is regulated, are illegal; 2. that the alternative specification of nickel steel and high carbon steel for the principal members of the suspended span is improper because it prevents fair competitive bidding and because it is wasteful of public moneys. The clauses of contract form and specifications which are directly involved in the judicial reasoning are few and brief, and are reprinted, below, followed by the full text of the decision.

The contract in question was intended to provide for furnishing the iron and steel work for the anchorages, and furnishing and erecting the towers, cables, suspenders, trusses, bracing, and floor framing, for the Manhattan Bridge, a wire-cable suspension structure, 1,470 ft. in span be-

tween towers and 2,920 ft. between anchorages. General drawings had been prepared by the Department of Bridges of the City of New York, giving dimensions and sections of material, and specifications had been drawn for quality of material, workmanship, and other conditions of work. The bids were asked on these drawings and specifications.* A single lump-sum bid was asked, accompanied by an itemized estimate, as per the following clauses of the Proposals for Bids:

j. The price bid must be a lump sum covering the cost of all material and work as set forth in the accompanying specifications and plans Nos. . . . . , which are to become part of the contract. . . . . .

k. Each bidder must calculate all quantities for himself and assume all responsibility therefor; and must accompany his bid with an itemized estimate of the quantities involved and the unit price of each item whereon his bid is based.

No provision was made for alternative prices to be named in each or any bid, although the specification provided for a choice of two materials for some 16,000,000 to 18,000,000 lbs. of metal, the main portion of the suspended span. These alternative materials, nickel steel and high carbon steel, were fully described in the specifications as to quality, manufacture, etc. The important question: which of the two materials was to be used, or rather, who was to decide which should be used, was left rather indefinite, being covered by the following clause of the specifications and by no other clause:

254. In the suspended superstructure, the main parts of the chords and of the diagonal web members of the trusses, the gusset plates connecting the diagonal web members to the chords and the chord splices shall be made of nickel steel, or of high carbon steel of the quality hereinbefore specified. All the rest of the material shall be made of medium carbon steel, except as otherwise indicated in the specifications or on the plans.

It is not stated whether the contractor or the Department of Bridges shall choose which material is to be used. The specifications and the contract form contain many clauses which make the Engineer† the sole judge in interpreting the specifications, in deciding all disputes between the parties to the contract, etc. This would seem to give the Engineer the choice between nickel steel and high carbon steel. On the other hand, the itemized estimate of quantities and unit prices, which was required to accompany the bid, contained an item reading thus:

Nickel steel or high carbon steel riveted work . . . pounds . . . (unit price) . . . (total price).

This item, when quantities (and presumably also unit prices) differ, must be held to indicate the basis of the contractor's bid, and may be interpreted as nullifying the right of the Department of Bridges to change his choice at a subsequent period. In favor of the Engineer's right to choose, on the other hand, is the following clause:

E. The Contractor shall furnish, deliver, construct, finish and fully complete the whole of the work as described . . . as shown in the specifications and by the drawings . . . and in accordance with such further details and instructions as the Engineer may from time to time furnish, approve or issue for the purpose of insuring the thorough completion of the work in the most efficient and expeditious manner.

Another clause, again, requires the Contractor to make, on the basis of the general plans and specifications, all working drawings, subject to the Engineer's approval; this clause may be held to give the Contractor a choice as to matters not fully described or shown in the contract plans and specifications.

We come now to the general clauses which the Court criticizes in its opinion. These cover the procedure of making alterations in or additions to the contract drawings and specifications. There are, mainly, four such clauses, all of which are printed here, although the Court's decision refers to only two of them:

H. The Engineer shall have the right of correcting any errors or omissions in the specifications and drawings, when such correction is necessary for the proper completion of the work herein stipulated and for the proper fulfilment of their intention; . . . it being further understood that if such correction should increase the cost of the work to the Contractor it shall be considered as extra work as hereinafter provided for.

EE. No claim for extra or additional work or materials shall be made by or allowed to the Contractor, unless before the performance of such extra or additional work the Commissioner shall have first authorized the same in writing, and the price or prices to be paid therefor shall first have been agreed upon in writing between the Commissioner and the Contractor, and the same shall have been done or furnished under a written order from the Commissioner given before the performance of such extra or additional work or the furnishing of such extra or additional materials. The aggregate price to be paid for extra or additional work or materials so authorized or ordered shall not exceed five per cent. (5%) of the contract price or total cost of the work and materials. . . .

GG. This contract and the specifications herein contained, and the plans hereafter referred to, may be modified and changed from time to time as may previously be agreed to in writing between the parties hereto, in a manner not materially affecting the substance thereof, or increasing the price to be paid, in order to carry out and complete more fully and perfectly the work herein agreed to be done and performed.

HH. If the conditions, at any time prevailing, require changes or alteration to be made, such changes shall be made and the work and materials required to be furnished to effect such changes, shall be made, done and furnished by the Contractor as under and a part of this agreement, and if such changes increase or decrease the cost of the work to the Contractor, of which the Engineer shall be sole judge, a reasonable addition to or deduction from the contract price shall be made and determined by the Engineer. If the work and materials required by such changes shall be different from those required or specified or reasonably implied by the terms and conditions set forth in this contract, specifications, plans and bid, then the increased or decreased cost of such work and materials shall be the subject of a supplemental written agreement by and between the parties as herein provided, by which the actual cost thereof shall be determined and fixed.

The last two clauses, GG and HH, are referred to by the decision. The provisions of clause HH whereby power is delegated to the Engineer to fix a price for extra work of certain kinds, and the provision which allows the Commissioner to make certain supplemental agreements for other kinds of extra work, are criticized as illegal. It does not appear that clause HH was considered in direct connection with clause EE, nor does the latter appear to have been declared illegal, although it involves supplemental agreements of the kind criticized in clause HH.

The decision of the court is as follows:

By Mr. Justice Dowling.

Gage v. City of N. Y. et al.—In this action, brought pursuant to section 1925 of the Code of Civil Procedure and chapter 301, Laws of 1892, the plaintiff seeks to restrain the Commissioner of Bridges of the City of New York, and the city itself, through its appropriate officers, from awarding the contract for the construction of the Manhattan Bridge, in said city, amounting to upwards of $7,000,000, to the defendant Pennsylvania Steel Company, or from acting upon its bid or any bid, and to have readvertised for new bidding the said contract, under specifications complying with the law and ordinances and which will inform all bidders of the quality and quantity of the work and material required. This is a motion for an injunction restraining the signing or executing of such contract pending trial. Plaintiff's general charge is that the proposed contract is illegal and wasteful of the public funds, and some four specific grounds for such charge are advanced. First, that the proposal for bids and proposed contract and specifications are so drawn as to prevent any free or fair competition; second, that the proposed contract reserves to the city power to make a new and substantially different contract, but with the Steel Company only, and without any competition; third, that the proposed contract delegates to the engineer of the bridge department discretionary power, which can be lawfully exercised, if at all, only by the head of the department; fourth, that the bid of the Pennsylvania Steel Company is not verified by the oath of the bidder. The last of these objections it is not necessary to consider, as it would be applicable only in case the proposed contract were held to be a proper one, and then would inure to the benefit of the next lowest bidder. As to the third objection, clause HH of the proposed contract virtually gives the engineer of the bridge department power to make a new contract by conferring upon him the right, if the conditions at any time require changes or alterations to be made, to require the work and material to effect such changes to be furnished by the contractor, of whether the changes increase or decrease the cost to the contractor the engineer is to be the sole judge, and he is to make and determine the reasonable addition to, or deduction from, the contract price. If the work and materials required by such changes are different from those specified, then a supplemental contract between the contractor and the city shall be made. This does not provide for such minor changes or modifications as perhaps are inevitable in any large public work. These are covered by clause GG of the contract, which reads as follows: "GG. This contract and the specifications herein contained and the plans hereafter referred to may be modified and changed from time to time as may previously be agreed to in writing between the parties hereto, in a manner not materially affecting the substance thereof, or increasing the price to be paid, in order to carry out and complete more fully and perfectly the work herein agreed to be done and performed."

Clause HH is made more sweeping, providing, as it does, firstly, for the possibility of changes and alterations in an indefinite amount, wherein the same work and materials as those specified are to be used, in which event the engineer solely determines the amount to be paid or deducted for said changes, and, secondly, for changes and alterations in an indefinite amount, wherein different work and materials from those specified are to be used, in which event a supplemental contract is to be made in writing between the contractor and the city, fixing the actual cost thereof. In the first event the engineer makes a new contract for the city. This he has no power to do. The charter of the city, section 419, requires contracts for city work to be made by the appropriate head of the department. There is nowhere any power given to an engineer to make a contract for the city, nor is it necessary to do more than state the proposition that no head of a city department can delegate the exercise of powers involving judgment and discretion. In the second event, a new contract is provided for which must be made with the original contractor, and for which no public competition or bidding has been had. Clause GG is sufficiently broad to cover any necessary changes in the contract not affecting its substance or increasing the cost of the work. If a contract and specifications are properly drawn this clause should be enough. Under clause HH a contract could be made for a fixed amount, and thereafter, by changes in plans and specifications or by additional work under the guise of changes or alterations, increased indefinitely over the original cost, without public bidding, and if the same character of work or materials were to be used in the additions, without even the consent of the commissioner. In my opinion clause HH is illegal. As to the second objection, the same is to be said as applies to the third. As to the first objection a question of much gravity is presented. Section 346 of the city ordinances, which by section 419 of the charter applies to and governs proposals for bids, requires, among other things, that they shall state the quantity and quality of supplies, or the nature and extent, as near as possible, of the work required. The purpose of this is that all prospective bidders may be equally informed of the work to be done and the materials to be furnished that the bidder may estimate intelligently and that the competition bidding may inure to the city's benefit and not be a mere form. In this case paragraph 254 of the specifications provides as follows: "Suspended Superstructure, 254. In the suspended superstructure, the main parts of the chords and of the diagonal web members of the trusses, the gusset plates connecting the diagonal web members to the chords and the chord splices shall be made of nickel steel, or of high carbon steel of the quality hereinbefore specified. All the rest of the material shall be made of medium carbon steel, except as otherwise indicated in the specifications or on the plans." Nickel steel is high carbon steel, to which a small proportion of nickel has been added. It is a very costly steel (defendants' affidavits, folios 212, 147 and 31). It is satisfactorily established by the affidavits, despite the attempts to figure out in various speculative and remote ways a different result, that there is a substantial difference at the present time between the cost of nickel steel and high carbon steel of the qualities specified. Over 16,000,000 pounds of one of these alternative materials were to be used. The estimates thereof vary from 16,247,000 pounds to 16,400,000 pounds. The Pennsylvania Steel Company, the successful bidder, estimated the quantity at the former figure, as appears from its bid, and it fixed the price per pound at 8 78-100 cents, which includes cost of putting it in place (see folio 125, plaintiff's affidavits). Their lump sum bid was based on the quantities and units they set forth in their bid (id., folio 122). Their schedule is in the alternative, "nickel steel or high carbon steel, riveted work." Plaintiff introduces proof that nickel steel, as specified, would cost, at 4¾ cents per pound, $779,000, and that high carbon steel, in quantities to equal its work (18,660,000 pounds), at 3 cents per pound, the market rate, would cost $559,800, or would cost a bidder having his own plant, at 1 2-10 cents per pound, $233,250. The affidavits on both sides concede a difference in the quantity in weight which will be required of high carbon steel if it is to be used in place of nickel steel. Even defendants' witnesses admit some difference in cost, which they reduce by considerations of the market price two years from now, difference in cost of putting in place and other reasons, to amounts varying from $7,721 to $10,000. It is established that there is a large difference in the present price of these alternative materials amounting, in my opinion, from the evidence, to close to $200,000. What justification is offered for such an unsatisfactory and costly method of specification? That nickel steel, while in use for a good many years and having proved itself extremely valuable for many purposes, has not been used under the conditions required in this bridge nor in members of such size, and has not been used in heavy structural pieces for a sufficient length of time to show positively that it is really superior to high carbon steel under these special conditions. Furthermore, that the question of its superiority over high carbon steel for this particular purpose is an open one to such an extent that it was incumbent on the engineers in charge not to specify definitely one or the other

*"The Steel Superstructure of the Manhattan Bridge," Eng. News, Aug. 3, 1905, p. 111.

†According to the contract form, the term "Engineer" designates: The Chief Engineer of the Department of Bridges or other engineer designated by the Commissioner of Bridges to act in his stead, or any assistant designated by the Chief Engineer having immediate charge of any portion of the work limited by the particular duties entrusted to him.

at this time. It is conceded that the material for the suspended superstructure will not be required for two years to come at least. The hope is held out that during that time experiments and actual results may show the superiority of nickel steel over high grade carbon steel. There is at present much variance between even the experts as to how much high grade carbon steel will be required to take the place of the nickel steel if the latter is not used. But who is to decide which is to be used? The bidding is on the alternative material. The city claims its engineer has the right to decide which of the two shall be ultimately used. The proposition is at least open to doubt. Upon the argument counsel for the Steel Company distinctly and unequivocally contended that his client had the right to determine which material he would furnish. He now withdraws that claim, but that such may be the effect of this contract, is shown not merely by his prior claims, but by the affidavit of his expert, Marshall, who swears (folio 149) that he "is familiar with paragraph 254 of the specifications, covering the use of either nickel or high carbon steel, and that he is of the opinion that under this section the contractor has the choice as to which of the two materials should be used." This is the view of the specifications and contract taken by an expert, who himself bid on the work for his company (folios 146, 147). What, then, becomes of the excuse for the use of alternative materials when it is still a debatable legal question whether the city at the end of two years could avail itself of the option as to the furnishing of the better material as then developed by trial? It is clear that the city, in this case, seeks to make a wasteful contract, based on specifications which are not sufficiently definite to afford an opportunity for fair competitive bidding. Here is a provision for the use of alternative materials, one much more costly than the other. It is claimed no one can now tell which one will ultimately be used. If all prospective bidders were alike informed and could not determine from the information which one they would have to furnish, they would certainly, as prudent business men, charge for the more costly; if any one or more knew what particular material would be called for they would obviously have an unfair advantage over the others. On the other hand, the city is paying for the higher priced material, which it may never use, while its right to call for it under the contract has been questioned by the successful bidder. The city should not call for bids for alternative materials unless it provides for so bidding that the quantities of either to be used are fixed with reasonable certainty, so that bidders may make their estimates with some safe guide to follow, and so that the bids when submitted show definitely the price for either material, with the city's right to call for either material when selected made plain. If the city is unable now to determine what material it will use two years hence for part of this bridge it should contract now only for so much of the work as it can fix the materials for with certainty, and call for bids for the rest when it determines what it proposes to use. Motion for injunction granted. Settle order on notice and at same time submit memoranda as to amount of security to be given pending trial.

The case will be appealed by the City of New York to the Appellate Division of the Supreme Court of the State for final decision on the application for injunction.

AN AUTOMATIC ELECTRIC WATER-HOIST AT AN ANTHRACITE COAL MINE.

A bucket water-hoist driven by an alternating-current induction motor and opening automatically has recently been installed at the anthracite mines of the Delaware, Lackawanna & Western Ry., near Schanton, Pa. The hoist was required to raise 4,000 gallons of water per minute a height of 550 ft., which calls for something over 600 HP. effective. Mr. H. M. Warren, Electrical Engineer of the railway company, specified an 800-HP. induction motor to drive the hoist. It was considered that reversing the motor with the hoist would not be practicable, on account of the large starting currents which would be drawn from the line; reversing clutches are therefore arranged for driving the hoisting drum, the motor running continuously in one direction. The motor drives a pair of bevel gears by means of a single bevel pinion; the bevel gears run loose on the shaft, but are fitted with Webster, Camp & Lane friction clutches, so that either gear may drive the shaft. The bevel gear shaft carries a pinion which engages the main gear on the drum shaft. The drums (2) are of cylindro-conical type, 16 ft. diameter in the cylindrical portion and 10 ft. diameter at the small end of the cone. They make a speed of about 15 r. p. m. at 550 ft. per min. hoisting speed. A head-frame of A-shape, 93 ft. high from base to center of sheave, carries, by 2-in. steel cables, two steel buckets of cylindrical shape, 6 ft. in diameter by 19 ft. 6 ins. deep. Each bucket has a capacity of 17 tons of water. In the bottom of each bucket are two lift gates with an area practically equal to the cross-section of the bucket. When the bucket reaches the top, these gates are opened automatically, and the water is discharged, through two laterally-opening spouts fitted below the bucket, into concrete basins on either side of the shaft. The bevel-gear clutches are operated by air cylinders fitted with oil cushion cylinders. A band brake is fitted to the two drums, lying centrally between them; it is held on by gravity, and is released by an air cylinder. Clutches [illegible] brake are controlled by electric air valves, [illegible] circuits are governed by means of a [illegible] nut driven by the drums, which at each [illegible] of its travel releases a switch drum actuating drive from the motor shaft, [illegible] the switch drum to make a quarter turn. [illegible] either air supply or current will release [illegible] operating clutch and apply the brake. An [illegible] brake on the motor shaft, operated [illegible] and held off by an electromagnet, stops the motor when the main current is interrupted. Limit stops fitted to the headframe cut off main current when the buckets travel beyond their proper limits. The entire operation, [illegible] automatic. The hoist makes a complete trip in 1 min. 50 sec. This includes a [illegible] stop at either end of the travel sufficient to let the upper bucket empty. The entire [illegible] was built by the Wellman-Seaver-Morgan Co., of Cleveland, O., to specifications of Mr. Warren. Most of the electrical control devices were furnished by the Electric Controller & Supply Co., of Cleveland, O.

VIEW OF AUTOMATIC WATER-HOIST INSTALLED AT MINE OF D., L. & W. R. R. NEAR SCRANTON, PA.

NOTES FROM THE ENGINEERING SCHOOLS.

WORCESTER POLYTECHNIC INSTITUTE.—By the will of the late Stephen Salisbury, the Worcester Polytechnic Institute receives a bequest of $200,000. This money comes without restrictions of any kind on the part of the testator. In addition to this bequest Mr. Salisbury, at the time of his resignation a few weeks ago from the Presidency of the Board of Trustees, made an additional gift to the Institute of $100,000, to be paid immediately.

UNIVERSITY OF WISCONSIN.—In accordance with an established practice, well known engineers will lecture to the students of engineering this year. There will be twelve lectures, on subjects related to chemical engineering, a new course in which has just been established. The first lecture of the present year was by Mr. Fred B. Wheeler, formerly of the Binghamton gas works and now associated with the Semet-Solvay Co., for whom he has recently installed a large by-product coke plant in Milwaukee. His subject was "A Survey of the Present Aspect of Gas Engineering." At the close of his talk Mr. Wheeler announced that he would offer a prize of $50 for the best thesis written by a member of the senior class of the college of engineering on some subject relative to the gas industry. The second lecture of the course will be by J. A. Faithorn, President of the Chicago Terminal Railroad, who will speak on "Railroad Rate Legislation."

The new chemistry building has been fully equipped for the study of electrical, physical, pharmaceutal and other branches of chemistry, and is now ready for use. Among the more notable features of the building is au auditorium, accommodating between 500 and 600 students; a general laboratory adjoining the auditorium, with 540 individual working desks; smaller research laboratories. These, together with offices and the like, occupy the first floor. Other laboratories, lecture rooms and a department library are on the second floor. The office and laboratory of the State Chemist occupies a part of the third floor.

Thus far this year the college of engineering has 711 students. Of this number 7 are graduate students. There are 136 in the civil engineering course, 95 in the mechanical engineering, 163 electrical engineering, 51 general engineering, 17 in the chemical engineering course. The freshman class numbers 278. The total enrollment of the University of Wisconsin this year will exceed 3,600.

A SECOND MUNICIPAL GOLF LINKS has just been opened by the county borough of Bournemouth, England. The first course was laid out in Meyrick Park, eleven years ago, and is said to have been profitable. The second course is 3½ miles long and was cut through thick heather in the land now being developed as Queen's Park. It may be added that Bournemouth is a seaside health and pleasure resort not far from Southampton, and that besides the golf links its municipal undertakings include an orchestra in the public gardens, properly housed in winter, and also an electric railway system.

NEW FREIGHT YARD AT ALEXANDRIA, VA., FOR THE WASHINGTON SOUTHERN RY. AND THE RICHMOND, FREDERICKSBURG & POTOMAC R. R.

By W. A. MacCart.*

The accompanying plan and profile show the new freight classification yard immediately north of Alexandria, Va., now under construction by the Washington Southern Ry. and the Richmond, Fredericksburg & Potomac R. R. This line, generally known as the Washington-Richmond line, forms the connecting link between the Pennsylvania and Baltimore & Ohio railroads, on the north, and the Atlantic Coast Line, Southern Ry., Seaboard Air Line, and Chesapeake & Ohio Ry. on the south, and is controlled and operated in the interest of the above named companies, portions of the line being used by most of them, and is the gateway through which must be interchanged a very considerable proportion of the traffic, both passenger and freight, provided by the territory traversed by these various roads.

There has been a large and constant increase in the amount of both passenger and freight business, and particularly of that class of the latter known as perishable, and to be in a position promptly and efficiently to handle it the Washington-Richmond line has, during the past two years, been engaged in improving its road by changes of alinement, and reduction of gradients and by double tracking (having at present about 50 miles of double track in operation), and as a very necessary finale to this work has been provided the interchange yard illustrated. The revisions made and in progress give on the new line, except in one instance, a maximum curve of 2°, and a maximum grade, northbound, of 0.6%, and southbound of 0.8%, the maximum before the changes being practically double these rates.

The interchange of traffic between the roads interested is now being conducted at different points, necessarily resulting in delays, which have been further increased by the congested conditions, at times arising from inadequate facilities in the vicinity of Washington, and after a careful consideration by a committee consisting of representatives from all the roads interested, of the various questions involved, the location north of Alexandria was decided upon as the most feasible one at which this work could be concentrated and the preparation of a plan for the yard was begun.

It will be observed from Fig. 1 that the passenger tracks are at the western side of the track lay-out and for a portion of the distance are parallel with and directly adjacent to the existing tracks of the Washington Southern Ry. For some distance north and south of the yard there are four tracks, two of which are for freight movement. These finally converge into a two-track system.

The movement of perishable or fast freight is largely northbound and therefor a separate receiving and classifying yard has been provided for this business, but at the same time so arranged that when necessary the receiving tracks can be used for ordinary freight passing over the hump. The receiving tracks northbound for fast freight were made for a 50-car train; for ordinary freight a 45-car train. The northbound advance tracks were made for a 50-car train. Southbound the receiving tracks will hold a 60-car train and the advance tracks a 50-car train. The classification tracks were made so that a portion of the number would hold a full train length.

In the profiles of the hump, Fig. 2, the enumeration of stations agrees with that shown on the plan. The grades adopted are fixed from experience gained elsewhere, allowance being made for the kind of traffic and different climatic conditions. The rate of grades approaching the humps, especially southbound, does not look well and may provoke criticism. In explanation it may be said that the location for the yard was fixed, and is between two summits of the main track grades and topography, in such a position that the humps are in the sag of the grade. This can be observed from the elevations given for main tracks on the lay-out plan, Fig. 1. The southbound cars have to leave the yard on an ascending grade and to reduce this by raising the hump would but have increased the grade into the southbound receiving tracks.

In order to save room in the length of the yard No. 7 ladders were used with No. 8 frogs, which is the ruling frog used, although there are a few specials needed for speed at the main connections or for other reasons.

Particular attention has been given to provide for the release of motive power and its easy access to ash pits, coal wharf, etc., and thence to the engine storage tracks, so that the delays frequently caused by the lack of facilities in this part of the operation will be reduced to a minimum. There are numerous instances to-day of delays in turning engines because of not readily accessible facilities.

Provision for cripple cars has been made in such a manner that bad order cars, southbound, which forms the greater percentage, can be classified directly into the shop tracks, and those northbound will have a comparatively short movement over the thoroughfare track in order to reach the shop tracks.

A feature not usually required in a yard of this character is a shed and tracks for the transfer of L. C. L. freight, which it is also proposed to have done at this point. The location is such as to be accessible from the yards in either direction with a minimum amount of shifting and provision is made for re-icing en route to the receiving tracks, northbound cars containing perishable freight.

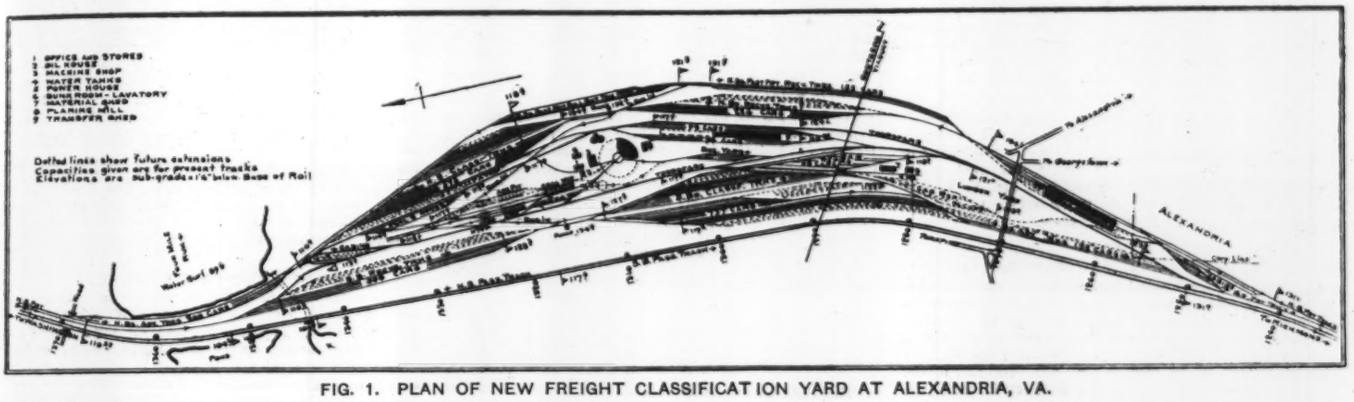


FIG. 1. PLAN OF NEW FREIGHT CLASSIFICATION YARD AT ALEXANDRIA, VA.

The thoroughfare tracks give free access to all portions of the yard.

The tracks to be provided at the present time, amounting to about 42 miles, are shown in full line and will furnish, exclusive of the repair and transfer shed tracks, standing room for 2,550 cars. Provision has been made for extensions and additions as shown by dotted lines, which will increase this standing room to 3,500 cars.

It will be noticed that the plan was further complicated by having to provide overhead crossings for both the Washington and Alexandria Turnpike and a branch of the Southern Railway. I might mention that the coaling wharf is equipped with the measuring pocket as used on the B. & O. R. R. This is necessary because of the different roads using the wharf and to enable an account to be kept of the amounts of coal used by each.

The estimated cost of the work based on what is proposed at the present time is about $1,000,000.

The plan for the yard was prepared in the office of Mr. Jos. T. Richards, Chief Engineer, Maintenance of Way, Pennsylvania R. R., at Philadelphia, by the writer, his Assistant Engineer on that class of work. The officers of the Washington-Richmond line, under whose supervision these improvements were projected and are being carried out, are W. D. Duke, General Manager; C. W. Culp, Assistant General Manager, and C. W. Haines, Chief Engineer.

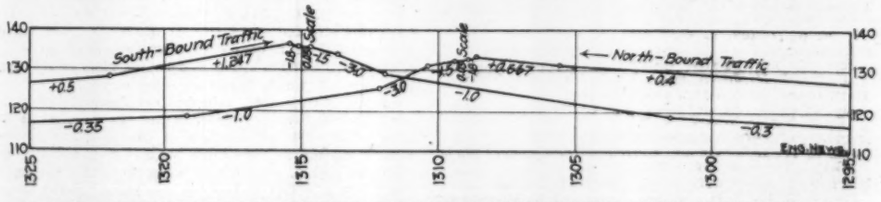


FIG. 2. PROFILE OF HUMP GRADES, FREIGHT CLASSIFICATION YARD, ALEXANDRIA, VA.

*Assistant to Principal Assistant Engineer, Pennsylvania R. R., Williamsport, Pa.

AN EMERGENCY APPROPRIATION OF $16,000,000 for the Isthmian Canal Commission will be asked as soon as Congress reassembles. The Commission has not only spent the entire $10,000,000 appropriated, but it has made contracts to the amount of $9,000,000 more, payment of which will become due before the end of the fiscal year. The Commission owes many bills, payment on which is overdue. These bills and those that will fall due before June 30th, together with the ordinary running expenses at Washington and on the Isthmus, salaries, wages, etc., at the rate of $1,000,000 a month, will amount to $7,000,000 more.

These heavy liabilities have been incurred in purchasing the plant for the construction of the canal, including dredges, steam shovels, locomotives and cars, and machinery of all sorts. Another important item is the sanitation of the Isthmus, the erection of the hospitals and hotels for the employees, and the introduction of a water and sewer system in the cities of Panama and Colon. By the end of June all of the plant will have been installed. After that time, however, expenses will be comparatively light as all the plant will be in position and only the running expenses will have to be met.

A SERIOUS RAILWAY ACCIDENT occurred on the Fitchburg division of the Boston & Maine Ry. on the evening of Nov. 26. A through passenger train, the Mon-

treal Express, north-bound from Boston to Montreal, ran at full speed into the rear end of a north-bound local train just pulling out of Baker Ridge, Mass., about 15 miles west of Boston. The express train was double-headed. It cut completely through the rear car and crushed the next car of the local; the wreck took fire and burned very rapidly, and the fire contributed largely to the list of fatalities. Seventeen persons were killed in the wreck, and very many others were injured. As far as known at present, the accident is chargeable to the engineer of the forward engine of the express, who passed signal lights and disregarded red fuse torches displayed by the forward train.

A WATER FILTRATION PLANT for the water from the Ludlow storage reservoir, Springfield, Mass., for use during the summer, or when there is trouble with growths of anabaena, was recommended by Mr. Allen Hazen, M. Am. Soc. C. E., of New York, on Nov. 20. On the same date the city council approved Mr. Hazen's plans for four acres of intermittent filters and appropriated money for the same. Since then a contract has been let for 30,000 cu. yds. of preliminary grading, at 29¾ cts. per cu. yd. The contractor is Mr. F. T. Ley & Co., of Springfield. Mr. E. E. Lochridge is engineer of the water department of Springfield.

A GASOLINE-ELECTRIC RAILWAY MOTOR CAR was run on an experimental trip on the Baltimore & Ohio Ry. Nov. 22. The power equipment of the car comprises an 80-HP. gasoline engine direct connected to a 50-KW. direct-current Westinghouse dynamo. The front truck of the car carries two 50-HP. Westinghouse motors. A storage battery of 108 cells is provided. Officials of the B. & O. Ry. and of the Pennsylvania R. R. made the trial trip.

STEAM MOTOR CARS have been adopted by the Railway Commission of South Australia with a view to the more economical handling of the light passenger and parcels traffic on two of its narrow gage branch lines (3 ft. 6 ins. gage), about 25 and 55 miles in length. The use of motor cars for track inspection work is also being extended, as they enable the officers to cover greater distances in a given time, with the result of increased supervision and economy.

AN ASSOCIATION OF PUBLIC HEALTH ENGINEERS has been formed under the patronage of the governments of the French-speaking countries of Europe and North Africa and will hold its first annual meeting at Paris, Nov. 22 to 25, 1905. The official title of the organization is: Association Generale des Ingenieurs et Hygienistes Municipaux de France, Algerie-Tunisie, Belgique, Suisse et Grand-Duche de Luxembourg.

PERSONALS.

Mr. C. E. Abbott has resigned his position as City Engineer of Eveleth, Minn., and will take a position with a zinc mining company in Southern Michigan.

Mr. F. T. Robertson, formerly General Superintendent of the Montana R. R., has been appointed General Manager of that road. His headquarters will be at Helena, Mont.

Mr. W. T. Penney, Apartado de Correo No. 178, Guatemala, C. A., has succeeded to the contracting business formerly carried on by Penney & Burton, that firm having ceased to exist, owing to the death of Mr. Burton.

Mr. Geo. F. Merrill, formerly Assistant Superintendent of Construction at San Antonio, Tex., has been appointed Civil Engineer and Superintendent of Construction, Quartermaster Department, U. S. Army, at Fort Dade, Fla.

Mr. Louis E. Foster, Engineering Aid in the U. S. Reclamation Service, has been granted a leave of absence from Nov. 16, 1905, to May 15, 1906, in order that he may take up a course of study at the University of California.

Mr. Alfred L. Hartridge, who is at present Assistant Engineer in charge of construction on the Ocean Shore R. R., at Colma, Cal., has been appointed Chief Engineer of the Grand Valley, Colorado River & South Pacific R. R., with headquarters at Basin, Utah.

Messrs. W. G. Shea and D. W. Bolich, of New York, have been appointed, by the Isthmian Canal Commission, Superintendents of Construction and Excavation. Mr. Bolich will leave for Panama at once, but Mr. Shea has been assigned duty in the United States for the present, examining and employing workmen for the canal.

Mr. R. G. Erwin, President of the Atlantic Coast Line R. R. since 1902, has resigned that position and is succeeded by Mr. T. M. Emerson, heretofore third vice-President in charge of traffic. Mr. J. R. Kenly, hitherto fourth vice-President, succeeds Mr. Emerson. Mr. Alexander Hamilton was elected first vice-President and Mr. C. S. Gadsden, second vice-President.

Mr. H. L. Newton has been appointed Superintendent of the Pacific Division of The National Lines of Mexico, with headquarters at Acambaro, Mex. He succeeds Mr. F. W. Baldwin, who has been appointed Superintendent of Transportation of the Interoceanic Ry., with headquarters in City of Mexico, to succeed Mr. J. H. Feehan. Mr. D. R. Caffey succeeds Mr. Newton as Superintendent of Terminals at the City of Mexico.

Mr. Judson C. Dickerman, a graduate of the Massachusetts Institute of Technology and recently Superintendent of the Merrimac Chemical Co., of Boston, Mass., has been appointed Assistant Professor of Chemical Engineering in the college of engineering of the University of Wisconsin. Professor Dickerman brings to his new work considerable experience in the manufacture of a large variety of chemicals, the construction of plants, installation and operation of machinery, and the development of new processes and methods in connection with chemical work.

Mr. J. J. Bernet has been appointed Assistant General Superintendent of the Lake Shore & Michigan Southern Ry., to succeed Mr. D. C. Moon, recently made General Superintendent to succeed H. C. Storrs, deceased. Mr. S. W. Brown has been appointed Superintendent of the Eastern Division, vice Mr. J. K. Bernet, promoted; Mr. F. H. Wilson has been appointed Superintendent of the Western Division, vice Mr. S. W. Brown, transferred. Mr. F. M. Smith has been appointed Assistant Superintendent of the Western Division. Mr. E. L. Mason has been appointed Trainmaster of the Michigan Division, vice Mr. F. M. Smith, promoted.

Obituary.

Samuel J. Anderson, promoter and President of the Portland & Ogdensburg R. R., died Nov. 19 at his home in Portland, Me., aged 81 years.

James Curry Ayers, the last surviving member of the firm of Samuel Ayers & Son, boat builders, died Nov. 23 at his home in Upper Nyack, N. Y.

William E. Decrow, General Manager of the Gamewell Fire Alarm Telegraph Co. for the New England States, died Nov. 25 at the Relief Hospital, Boston, Mass.

Thomas J. Long, vice-President of the Atlantic, Gulf & Pacific Co., New York, died Nov. 20, aged 53 years. A fuller notice concerning Mr. Long is given elsewhere in this issue.

Thomas Leiper Patterson, one of the oldest active civil engineers in the United States, died Nov. 25 at Cumberland, Md., of pneumonia, in his ninetieth year. Mr. Patterson was civil engineer in the construction of the Philadelphia, Wilmington & Baltimore R. R. Later he was engineer in charge of the construction of the Chesapeake and Ohio Canal, and still later of the Georges Creek and Cumberland Railway. He was educated at the University of Virginia. Mr. Patterson followed his vocation until a few months before his death.

Charles Cuttriss, M. Am. Inst. E. E., died Nov. 18 in the J. Hood Wright Hospital, New York. Mr. Cuttriss had been head of the Electrical Department of the Commercial Cable Co. for a number of years, and two years ago he held an important position in the laying of the Pacific cable by his company. At that time he contracted malaria, which so affected his health as to interfere with his work. It was, while suffering from a fit of temporary insanity brought on by the fever, that he shot himself in the mouth, dying shortly afterward at the hospital.

ENGINEERING SOCIETIES.

COMING MEETINGS.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 4 and 5. Annual meeting at New York, N. Y. Secy., W. H. Ross, 258 Broadway, New York, N. Y.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 5-8. Annual meeting at New York, N. Y. Secy., F. R. Hutton, 12 West 31st St., New York.

ENGINEERING ASSOCIATION OF THE SOUTH.
Dec. 15, 16. Annual meeting at Birmingham, Ala. Secy., H. M. Jones, Berry Block, Nashville, Tenn.

AMERICAN ECONOMIC ASSOCIATION.
Dec. 27 to 29. Annual meeting at Baltimore, Md. Secy., F. A. Fetter, Ithaca, N. Y.

MICHIGAN ENGINEERING SOCIETY.
Jan. 9, 10, 1906. Annual convention at Lansing, Mich. Secy., F. Hodgman, Climax, Mich.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 9 to 12, 1906. Annual convention at Milwaukee, Wis. Secy., C. C. Brown, Commercial Club Bldg., Indianapolis, Ind.

NEW ENGLAND WATER-WORKS ASSOCIATION.
Jan. 10. Annual meeting. Secy., Willard Kent, Narragansett Pier, R. I.

INDIANA ENGINEERING SOCIETY.
Jan. 18, 19, 20. Annual meeting at Indianapolis, Ind. Secy., C. C. Brown, Commercial Club Building, Indianapolis, Ind.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.
Jan. 17, 18, 19. Annual meeting at Rockford, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Block, Chicago.

AMERICAN INSTITUTE OF MINING ENGINEERS.
Feb. 21. Annual meeting at South Bethlehem, Pa. Secy., R. W. Raymond, 99 John St., New York, N. Y.

NORTHWESTERN CEMENT PRODUCTS' ASSOCIATION.
Jan. 17, 18, 19. Annual convention at Minneapolis, Minn. Secy., F. H. Chapin, 10 N. Third St., Minneapolis, Minn.

ENGINEERS' SOCIETY OF WESTERN NEW [illegible]—The annual meeting of the society will be held [illegible] rooms of the society, 533 Ellicott Square, Buffalo, on Dec. 5. A business session is scheduled for 4 when officers will be elected. Professional papers [illegible] read at the evening session. Secy., H. B. Alverson.

INDIANA ENGINEERING SOCIETY.—The date [illegible] next annual meeting has been changed to Jan. 18 to 20. Numerous papers have been promised for the meeting, among them the following: "The Reclamation [illegible] of the U. S. Geological Survey," by Mr. M. O. Leighton; "Street Paving," by Mr. W. S. Moore, of Mishawaka; "Concrete Masonry," by Mr. J. Finan, Jr., Hamilton; "A Water Supply and Electric Light Plant for Towns," by Prof. R. L. Sackett; "Some Experiences in Street Paving," by Mr. J. S. Spiker, of Vincennes; "Some Architectural Features of Concrete Block Construction," by Mr. L. H. Gibson, of Indianapolis; "Soft Coal," by Mr. R. P. King, of Indianapolis; "Shop Management," by Mr. H. Diemer, of Indianapolis; "The Power Required to Operate Machine Tools," by Mr. R. C. Stevens, of Indianapolis.

WASHINGTON SOCIETY OF ENGINEERS.—An informal meeting of civil, electrical, mechanical, mining, military and naval engineers was held in Washington, D. C., on the evening of Nov. 23, and an organization was formed to be known as the Washington Society of Engineers. The meeting was attended by over one hundred of the leading members of the profession in the city; a number of army and navy officers were present.

The greater part of the evening was given over to the adoption of a constitution for the society and discussion of amendments thereto. Admiral C. W. Rae, U. S. N., acted as temporary chairman and D. W. Bliss, of the Bliss Electrical School, served as secretary. The temporary committee designated to draft a constitution and make the call for the meeting consisted of Admiral C. W. Rae, Engineer-in-Chief, U. S. N., chairman; Col. John Biddle, Engineer Commissioner of the District; H. M. Wilson, civil engineer; W. A. McFarland, Mechanical Engineer; C. W. Hayes, Mining Engineer; and L. D. Bliss, Electrical Engineer, Secretary. The election of officers will be held on the third Thursday in December.

WESTERN RAILWAY CLUB.—At the meeting held at the Auditorium Hotel on Nov. 21, a lecture on "The Care of Locomotive Boilers," illustrated by stereopticon views, was given by Mr. M. E. Wells, Traveling Master Mechanic of the Wabash Ry. A large proportion of the lecture dealt with water circulation and the handling of the boiler feed, and these are matters upon which it is found that enginemen and firemen need much education. It is very common practice to fill up the boiler when the train is waiting on a side track, and as there is very little circulation the cold water settles to the bottom, and there is but a slight drop of the steam gage. But when the engine starts to pull out, the increased circulation causes the cold water to mix with the upper body of hot water, lowering the general temperature and bringing the steam pressure down rapidly, so that the fireman has hard work to keep steam up. This practice also caused many of the troubles from leaky tubes. In the old days, when feed pumps were used instead of injectors, there was less trouble of this kind, as the boiler could only be supplied with water while the engine was running.

Several methods and devices to prevent the cold feed water from going directly to the bottom of the boiler were illustrated. In one of these, the check valve is on top of the boiler and the pipe is fitted with a spreader to spray the water into the steam space. In other cases, a pocket is attached to the inside of the boiler shell, opposite the check valve opening, and the water overflows from this into the upper part of the boiler. Another device consists of a couple of long horizontal pipes suspended in the steam space, and having slots in the upper part through which the feed water escapes.

Another matter dealt with was the character of firebox steel, and Mr. Wells considered that the material as now required by the specifications of the American Railway Master Mechanics Association (55,000 to 65,000 lbs. tensile strength) is not so well adapted to the purpose as the steel of about 50,000 lbs. formerly used. He exhibited a number of locomotive boiler records showing that fireboxes of the latter material lasted from 8 to 12 years, while fireboxes of the harder steel put into the same engines lasted only from 3 to 5 years.

Mr. Wells considered that "bad water" was too often an excuse rather than a reason for boiler troubles, and cases were cited in which the scale from bad water was blamed for troubles on new engines which had not had time to become scaled. In this connection, Mr. A. E. Manchester, Superintendent of Motive Power of the Chicago, Milwaukee & St. Paul Ry., stated that he had had mysterious troubles with some new boilers and had come to the conclusion that they were due to oil and dirt left in the boilers.